MACKENZIE'S

MARITIM

SURVEYING

A

TREATISE

OF

MARITIM SURVEYING,

IN TWO PARTS:

WITH A

PREFATORY ESSAY

ON

DRAUGHTS AND SURVEYS.

BY

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A

PREFATORY ESSAY

O N

Draughts and Surveys of the Sea-Coast.

NO Branch of practical Geometry has been so little considered by Men of Science as Maritim Surveying. This Subject has never been particularly treated of by any Author, nor taught by a Master; nor have Surveyors given any Account of their Operations and Procedure in such Surveys. To this Reserve of Writers, and Silence of Practitioners, it may be ascribed, that an Art of such great Importance in Navigation has hitherto received so little Improvement; that in Practice little or no Distinction is made between Land-surveying and Coast-surveying, though they differ essentially from each other in their Nature and Circumstances; that so few Draughts are found to answer the End proposed by them; and that the Merits of the Draughts to which Seamen trust their Lives and Fortunes, are seldom judged of by any other Rules than the Recency of the Publication, the Neatness of the Engraving, the Authority under which the Survey was executed; or, sometimes, by the Rank and Reputation of the Persons to whom they are inscribed. Had Coast-surveying been considered with the Attention it deserves, the various Sorts of Draughts which are often indiscriminately made use of at Sea, would, before now, have been characteristically dis-

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tinguifhed from one another ; the Particulars of which a complete
Draught confifts would have been fufficiently known ; the feveral
Methods of furveying compared together, and the moft perfect Man-
ner pointed out and explained. As yet, whoever undertakes a Sur-
vey of the Sea-coaft is under the Neceffity of devifing a Plan of Pro-
cedure for himfelf, and performing moft of the Operations by his
own Ingenuity and Skill in the Principles, without the Advantage of
the Speculations and Experience of others to affift him. This Want
of previous Inftruions, and the Difficulty and Trouble of frequent
Inveftigation, feem to be the chief Reafons that Coaft-furveyors com-
monly follow that Method which their antecedent Bufinefs or Ap-
plications fuggeft, rather than that which a thorough Knowledge of
the Theory, and ftrict Attention to the Nature and Circumftances of
the Coaft would have directed. The Navigator, or experienced Sea-
man, conftructs his Charts chiefly from Sea-journals of Courfes and
Diftances : the Engineer and Land-meafurer, by a continued Men-
furation of Sides and Angles ; or by a connected Chain of Triangles :
Some meafure their Diftances with a Wheel, fome with a Chain,
and others with a Rope : one takes his Angles with a Needle, one
with a Theodolite, and a third with a common Compafs : the Way
in which one proceeds in a Survey neceffarily reftricts his Performance
within narrow Bounds : another takes a Method, by which he fur-
veys more Coaft in one Year, than he could travel over in three ;
furveying a little himfelf, and copying a great deal from others, with-
out diftinguifhing the certain from the uncertain.

Wherever the Safety of Shipping is concerned, the Public has a
Right to fome Satisfaction with refpect to the Nature and Grounds
of the Publication. It is not fufficient to fay, in the Title, that it is
an actual Survey ; or, a new and accurate Survey : it ought to be ac-
companied with, at leaft, a fhort Account of the fundamental Ope-
rations, and Manner in which the Survey was conducted. This
would

would enable Seamen to form some Notion of the Merits of the Draughts they were trusting their Lives to, and to judge in what Circumstances they might be depended on, and in what Circumstances a Dependance on them would be imprudent. A faithful Answer to the following Questions would be sufficient for this Purpose, and might be easily subjoined to the Title of any Draught.

1. *How long was the fundamental Base-line? Where, and how, was it measured?*

2. *In what Manner was the Survey carried on from that Base-line? And with what Instruments were the Angles taken?*

Or, if the different Sorts of Draughts were classed under different Heads, with Epithets, or Appellations, significant of the Manner in which each was done, and published with that Epithet, or under that Appellation, only; this would in a great Measure answer the same End, and point out readily the Nature and Peculiarities of the several Draughts. Such a Capitulary is attempted in the following Enumeration of Draughts and Surveys; and will serve to explain what is here proposed.

1. A GENERAL, or NAUTICAL, CHART, is commonly constructed and drawn by some experienced Seaman from his own Observations and Journals of the Courses and Distances from Head-land to Head-land, and Point to Point; with the intermediate Spaces filled up from such Charts or Maps as are at Hand, or are in most Repute. Sometimes on the Margin of the Chart are added larger Sketches of some of the most noted Harbours he is acquainted with, drawn from his own Memory, or copied from others. These Charts are always done by a very small Scale, so as to comprehend a large Extent of Land and Sea. Rocks and Shoals are seldom, or or never, particularly examined, but laid down according to their ap-

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parent Diſtance from a noted Head-land, or by the Ship's Reckon-ing, which is looked upon as a ſufficient Direction for avoiding them.

In theſe Charts, as all the Diſtances are either taken by the Eye, the Log-line, or the Ship's Traverſe, without any certain Allowance for the Influence of Tides and Currents; and the Courſes, for the moſt part, deduced from the Reckoning, or ſometimes taken at Sea by a Compaſs; great Exactneſs is not to be expected: and as the Scale is very ſmall, no ſtriking Reſemblance of any Part of the Coaſt can be expreſſed in the Draught, to point out with Certainty where Shoals or Harbours lie. Notwithſtanding theſe Diſadvantages, ſuch general Charts are neceſſary to Navigation: and ſome take the Charge of conducting Ships who have no better Draughts to rely on: but then, if they are not particularly acquainted with the Places they are bound to, they ought always to carry a Pilot, who knows them; and never to truſt to ſuch Charts farther than for general Courſes at free Sea.

When theſe general Draughts are corrected by Latitudes and Lon-gitudes carefully obſerved; and when the Publiſher is ſo juſt to himſelf and others, as to diſtinguiſh ſuch Courſes, Diſtances, and Tracts of Navigation as are delineated from his own repeated Obſervations and Experience, *from* thoſe which he has copied, or taken on Truſt from others; then they become very ſerviceable in ſailing from Land to Land, or along an open Coaſt; but near the Shore, where the Dan-ger is greateſt; and in bad Weather, when a Ship is under the Ne-ceſſity of running for a Harbour, or ſheltering in a Bay, theſe ge-neral Charts are of little or no Service. In ſuch Circumſtances, larger and more particular Draughts, or a ſkilful Pilot, are indiſ-penſibly neceſſary.

Charts

Charts of this Sort will not be brought to their utmoſt Perfection, till ſkilful Perſons are ſent on purpoſe, with good Inſtruments, to obſerve, on Land, or near it, the Latitudes and Longitudes of the moſt remarkable Points and Promontories which Ships have moſt frequent Occaſion to ſail along, or to *make*, when they approach the Land. If this ſhall ever be done, diſtant Views of the Land ought alſo to be taken; and each Obſervation, with its ſeveral Circumſtances, ſhould be preſerved and publiſhed along with the Chart conſtructed from them. A few Years, perhaps, would be ſufficient to accompliſh this on both Sides of the Atlantic Ocean; or of the German, or North Sea: and would produce an accurate and laſting Chart of theſe Parts, which would never after need Correction. When a proper Manner of Surveying is more generally underſtood by ſeafaring Gentlemen, the intermediate Parts might be ſurveyed in a particular and complete Manner; which (excepting ſome Banks and Channels that are of a variable Nature) would be as permanent as the other. If, by the Aſſiduity of Theoriſts, or the Ingenuity of Artiſts, that important Problem of finding a Ship's Longitude at Sea, ſhall become eaſy to ordinary Seamen, ſuch a Chart will be neceſſary to render that Diſcovery fully ſerviceable to Navigation.

2. ABBREVIATED COLLECTIONS OF DRAUGHTS, as they comprehend a great deal of Coaſt in a ſmall Compaſs, are of the ſame Nature with the nautical Chart laſt mentioned, and can ſerve for no other Purpoſes in Navigation but to direct Ship's Courſes from Land to Land, or from Promontory to Promontory along a Coaſt. Theſe are commonly the Chamber-performances of Map-ſellers and Drawers, who perhaps never ſaw any of the Places they delineate, and, for that Reaſon, cannot be ſuppoſed capable of making a proper Choice of the Draughts they abridge. Beſides, in contracting a Diverſity of Scales and Draughts into one, by the utmoſt Care they can hardly avoid introducing new Errors, or Inaccuracies, over and

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above what might have been in the Originals before. By the Diminution of the Figure, the Diſtinctneſs that was in the Originals will certainly be loſt in the Abbreviation. Theſe miniature Collections often do more Prejudice than Service to Navigation : for, on account of the comparative Lowneſs of the Price, and the Names and ſpecious Authorities annexed to the Title, many are inconſiderately led to purchaſe and preſerve them; while the Originals, that would have been of much more Service, are as inconſiderately neglected and loſt.

3. A Memorial Sketch is, a Delineation of a Harbour, or any Part of a Coaſt, from the Memory only; without Notes, or immediate Sight.

When ſuch a Sketch is made by one who has been often in the Place, or who has viewed it with particular Attention, it may convey a general Idea of a Bay, Harbour, or Iſland, fit to gratify Curioſity, or enlarge Geography, by ſhewing that ſome ſuch Places are there: but as every Part of the Sketch was at firſt by Gueſs, and that Gueſs delineated by Recollection only, the whole muſt be very uncertain, and of little Service to Shipping ; farther than to admoniſh Sailors to keep a Look-out when they ſail that Way. It is likely that moſt of the Iſlands in the *Eaſt Indies*, *Africa*, the *South-Sea*, and on the Coaſt of *Norway*, have been drawn and inſerted in our Draughts after this Manner.

4. An Eye-Sketch is, a Delineation of any Harbour, or Part of a Coaſt, done by the Eye at one Station, without meaſuring Diſtances ; and drawn according to the apparent Shape and Dimenſions of the Land.

Though here neither Bearings, Diſtances, the Figure of the Land, nor the Poſition of Rocks or Shoals, can be exact; yet a

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good Drawer may make fuch a Sketch convey a fufficient Notion of a fmall Bay, Harbour, or Ifland, to be ferviceable on fome Occafions; and in moderate Weather, with the Help of the Lead, to direct a Veffel to the fafeft Channel and ordinary Anchorage. A great deal of the Benefit of fuch a Draught depends on chufing an advantageous Station to take it from, fo that the principal Parts of the Harbour, or Bay, may not be too far from the Eye; for the remoteft Parts will always be moft unlike. It is likewife of Advantage to chufe the Station near the Sea, on that Side of the Bay, or Harbour, which is next the common Channel; becaufe remarkable Parts on that Side of the Bay and Channel may then be delineated according to their true Bearings, by a Compafs. Such a Sketch is foon made by one moderately fkilled in Drawing: and if fea-faring Gentlemen, when they are in Places unknown, or not furveyed, would be at Pains to take fuch Sketches, it would be of fome Service both to Navigation and Geography.

5. An AMBULATORY DRAUGHT, is made by walking along the Shore, taking the Bearings from Point to Point with a Compafs, eftimating their Diftances by the Eye, and fketching the Figure of the Coaft between them. If to this, remarkable Objects on Land are added, and fuch Rocks, Shoals, and Ledges as are vifible at low Water, or by Breakers, with the Depths in the principal Channel, and in the Anchorage, the Draught will be a diftinct Reprefentation of any fingle Bay, or Harbour, and prove ferviceable to Veffels on feveral Occafions. But if it is continued for fome Leagues on an irregular Coaft, the erroneous Diftances will affect the Bearings, and alfo the Figure and Dimenfions of the whole Draught: grofs Errors in the more confiderable Parts muft then be corrected by making the lefs confiderable Parts more erroneous; till at length the whole will become too evidently diftorted and out of Proportion to admit of farther Alterations; and then of Neceffity

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the Survey muſt be diſcontinued.   It is likely that moſt of the par-
ticular Draughts uſed by Seamen have been made in this Manner.

When ſuch Draughts are confined to ſmall Parts of a Coaſt, or to
ſingle Bays, or Harbours, the Errors in them are leſs ſenſible; and
they become ſerviceable by exhibiting plainly what Kind of Bays
and Harbours are to be met with on that Coaſt: and, when Rocks,
Shoals, and Soundings are inſerted, they will be found a pretty good
Direction for Veſſels that may happen to fall in with them, provided
at the ſame Time they are ſure what Harbour it is which they have
fallen in with: but to Strangers, and ſuch as are not well acquainted with
the Land before, ſeparate Draughts of Harbours will not be found
of great Uſe, eſpecially in bad Weather, when a Direction is moſt
needed; becauſe of the Difficulty of finding where a particular Har-
bour lies, and the Danger of a Miſtake in running for it.   A Ship
muſt be off the Mouth of the Harbour before ſuch a Draught can
be of Uſe; and the Pilot that is neceſſary to bring her thither, may
likewiſe carry her in.

When one makes a Draught of a Bay, or Harbour in this Manner,
at the ſame Time that he goes along the firſt Side delineating it, the
magnetic Direction of the ſeveral Points and Heads on the other
Side ſhould be drawn out on the Paper, and their Poſitions limited
to that Direction, which will render the Bearings right, however
erroneous the Diſtances may be: if this is neglected, both the Diſ-
tances and oppoſite Bearings will be falſe, and the Draught unlike in
every Reſpect.

None of the three laſt-mentioned Performances ought to go under
the Name of Surveys, becauſe there is no Menſuration of Diſtances
in them, nor any Thing determined in a geometrical Manner.

6. A DISJUNCT SURVEY is, when the Harbours, Bays, or
Iſlands in any Country, are each ſurveyed ſeparately in a geometrical
Manner.

Manner. Or, when one, or more, ſtraight Lines are meaſured on a Level Plane in each Harbour, Bay, or Iſland; the Angles taken with a good Inſtrument, and the Diſtances of the ſeveral Places determined from thence trigonometrically.

In this Survey, all the Rocks, Shoals and Channels are ſuppoſed to be carefully examined, and diſtinctly delineated, by a large Scale; and the Buoys, Beacons, Land-marks, remarkable Hills, Groves of Trees, Churches and Buildings, neceſſary for directing Veſſels on any Occaſion, inſerted in their proper Places and miniature Forms; the various Diverſities of the Sea-coaſt, and of the Rocks, Shoals and Sand-banks along it, repreſented ſo as theſe Varieties may be readily known by inſpecting the Draught. Such a Draught will be a minute and exact Repreſentation of each Place, as far as relates to Shipping; and is, or ought to be, the moſt complete of any, within the Limits of the Bay, Harbour, or Iſland ſurveyed. There is, however, one material Defect not to be avoided in Draughts of this Sort; which is, that Rocks, Shoals and Sand-banks that lie off the Harbour, or Coaſt, can ſeldom be laid down either in their juſt Dimenſions, or in their proper Places; nor can interſecting Bearings be given for finding them out; nor Land-marks for avoiding them on all Sides. The Reaſon is, each Draught comprehends ſo ſmall an Extent of Coaſt, that Objects properly ſituated for theſe Purpoſes cannot be included in it. *Lewis Morris,* in his Draughts of the Harbours of *Wales,* and Captain *Collins,* in his more diſtinct Draughts of Harbours in *Britain* and *Ireland,* very ſeldom give any Deſcription of the Rocks and Shoals they repreſent, nor Directions for avoiding them on all Sides: and theſe they deſcribe are ſo ſuperficially done, that it is not without much Trouble and Searching that the Shoal can be found at all: the Nature of their Surveys would not admit of being ſo particular as that requires. Detached Draughts of ſmall Extent, though never ſo exactly done, will not be found of much more Service to Navigation than the ambulatory Draughts before-mentioned:

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for neither of them are of Use till a Veffel is in the Mouth of the Harbour; and then, the apparent Similitude between the ambulatory Draught and the Land, will direct her to the proper Anchorage as well as an exact Similarity in the geometrical Draught; for in failing along, the Eye cannot perceive the Difference. No one that was not acquainted with the Coaft, ever ventured to run for a Harbour by the detached Draughts that are to be feen on the Margins of fome Maps and Charts; nor by thofe done by *Collins*, or *Morris*, though there is a general Chart along with them. However, difjunct Draughts, when well executed, give great Satisfaction, by making the Nature and Capacity of Bays and Harbours exactly and diftinctly known, and are good Remembrancers to thofe who have been in thefe Harbours, and are fo well acquainted as to know the Land at fome Diftance: but a Stranger to the Coaft can receive very little Benefit by them, except that they may prove a Check on unfkilful Pilots.

7. A LINEANGULAR SURVEY is, when the Coaft is meafured all along with a Chain, or Wheel, and the Angles taken at each Point and Turn of the Land with a Theodolite, or magnetic Needle

Some few Bays, that happen to be bordered with Sand or Marfh, may be fuited to fuch Operations; and then, if great Care is taken a pretty exact Survey may be made. But, it is only a fmall Part of any Coaft that is level and fmooth enough to admit of a continued Menfuration with any tolerable Degree of Exactnefs. And, when it is confidered that every Error, or Inaccuracy, in any one meafured Diftance, occafions a proportional Error in all the other fubfequent Diftances; that every Inaccuracy in the Angles affects all the other fubfequent Angles and Sides; that, among fuch a Number of Angles, Inaccuracies, perhaps Miftakes, are hardly to be avoided; and when they happen, harder to be found out, fo as to be properly corrected; when thefe Things are confidered, it will not be reckoned

a Paradox

a Paradox to affirm, that an irregular Coaſt may be ſurveyed by the Eye and a Compaſs, as exactly as in the lineängular Manner. A Surveyor will eaſily be ſatisfied of this, if he has ever tried to ſurvey an irregular Field, or ſmall Iſland, by meaſuring all the Sides, and obſerving the Angles between them : by his Field-book their Circumferences will never meet on the Paper. *That Reproach* of Surveyors is not to be wiped off by ſuch a Procedure. Surveys taken in this Way are tedious, troubleſome, and require many Hands conſtantly imployed : the Diſtances by the Draught, and by obſerved Latitudes, differ widely from each other ; and the whole will come out larger than the Truth ; except Errors in the Angles ſhall happen, to counteract the Errors in the Sides ; and in that Caſe, particular Parts muſt be very much out of Proportion. If the Diſtances are meaſured with a Wheel, inſtead of a Chain ; or the Angles taken with a Needle, inſtead of a Theodolite ; then the whole, and particular Parts, will be ſtill more erroneous. Lineängular Surveys that are continued beyond the Limits of a ſmall Bay or Harbour, are in no Caſe to be depended on : and very few even of theſe, can be exactly done in that Manner. This, however, ſeems to be the moſt common Method of geometrical Surveying.

8. A Trigonocatenary Survey is when one long Baſe-line is carefully meaſured on a level Plane, the Angles taken with a good Inſtrument, and from that Baſe-line a connected Series of Triangles carried on along the whole Coaſt, by which the Diſtances of the ſeveral Heads, Points and Flexures of the Shore are determined trigonometrically.

By this Procedure, one Source of Error in the former Method is avoided, viz. that which ariſes from a continued Menſuration : but the other, perhaps no leſs conſiderable, which is found, by conſtant Experience, to flow from a long Chain of Triangles all depending on one another, ſtill remains to affect the mutual Bearings and Diſ-

tances

tances of the Places.   This Manner of furveying is liable to much the fame Inaccuracies and Imperfections as the lineängular, only not to fo great a Degree.   When Objects, fharp enough for forming the angular Points with Precifion, are rarely to be met with (which is the Cafe on every Coaft) Errors in Angles muft neceffarily arife: one Error caufes another, that a third, and fo on; each increafing the Inaccuracies of the fubfequent Triangles: and, after they have infenfibly run through a few trigonal Links of the Chain, their Source becomes indifcoverable; and, at length, the Error of the whole too great to be corrected in the material Parts, without making very grofs Errors in other Parts: the Survey muft then of Neceffity be either broke off, or continued with very ftriking Imperfections.

If a Coaft happens to be fo circumftanced, that level Planes may be met with on it at proper Diftances from each other, and new Bafe-lines are meafured on thefe Planes; and if Poles, or Signals, are fet up forming Triangles all along the Coaft; then, with great Care, the Angles may be taken, and the Survey continued with fufficient Exactnefs.   But, fuch a Procedure would be extremely tedious: a Life-time would hardly be fufficient to furvey the Coaft of one Kingdom in this Manner, with the Care it requires.   But as Planes of a fufficient Length and Smoothnefs are feldom to be found on any Coaft, whoever carries on an extenfive Survey this Way, will be often under the Neceffity of making random Alterations in the Draught, at leaft at every new Bafe-line; that the feveral Parts may connect with one another, and that the whole may agree better with obferved Latitudes.   And, after the whole is put together one Way or another, the original Scale muft be changed, and a different one fubftituted in its Place, that is better adapted to the Latitudes, and to the Dimenfions of the whole: that is, a Survey taken in this Way muft be finifhed, before the Scale that fuits it is known.

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9. An OROMETRIC SURVEY is, when one long Bafe-line is exactly meafured, and the Diftance of the Summits of two, or more, high Mountains in the Neighbourhood found from thence trigonometrically: then, by Angles taken on thefe Summits, the Diftances of all the Points, Heads, Turns and other vifible Objects on the Coaft are afcertained; and from them the Pofitions of other intermediate Objects and Places. From thefe Mountains likewife, the Diftances of other Mountains, farther along, are found; which ferve in the fame Manner as the firft, for determining Diftances along that Part of the Coaft which is adjacent to them.

By this Way of furveying a Coaft, when the Foundation is carefully laid, the Errors which all the fore-mentioned Methods are liable to, are in a great Meafure guarded againft: for, the Error, or Inaccuracy, of any one Diftance, or Angle, is not communicated to the reft, but confined to that Diftance, or Angle alone, or perhaps to an adjacent Point or two befides, which are not of great Confequence in the Draught, nor affect the Pofitions of other Parts. Therefore, in a mountainous Country, where the fundamental Triangles are few, and the Nature of the Coaft otherwife favourable, a Survey may be continued a great Length, without any Error confiderable enough to affect the Extent of the whole together. But then Shores are generally fo low, and of fuch a Nature, that particular Parts can feldom be perceived from the Tops of two remote and high Mountains; even large Buildings are not often to be feen from thence: and though Points and Promontories, in Grofs, may be perceived from both, yet it is fcarce poffible to diftinguifh the fame Part of them from each Mountain. This will render the Angles, and of Confequence, the Diftances inaccurate; and caufe the obferved Points and Heads in the Draught to extend more, or lefs, from the reft of the Coaft than they ought: and other Diftances and Bearings that depend on them will participate of their Error. However, if a moderate Degree of Care is taken, thefe Errors will

not

not be confiderable, and the Draught, in general, may agree fuffi-
ciently with obferved Latitudes and Longitudes. Though by this
Method an extenfive Survey may be carried on with more Certainty
and Exactnefs than by any of thofe before-mentioned, yet there is
Ground to believe that it has feldom been put in Practice.

10. A STASIMETRIC SURVEY is, when the mutual Diftances
of three, or more, proper Objects are carefully meafured; and by
Means of thefe Objects, the Pofition and Diftance of all Stations
along the Coaft determined trigonometrically, each at its refpective
Station alone, independent of one another.

By this Manner of Surveying, the Errors which all the other
Methods are liable to are avoided : for, the Diftances along the Coaft
depending intirely on the Diftances of three Objects chofen at Plea-
fure, the moft proper may be felected for that Purpofe : or, if
proper Objects are not to be had, others may be adapted to it by
Signals, and their mutual Diftances previoufly determined to any
Degree of Exactnefs. And if, by Overfight, an Error fhall happen
in any Part, it is confined to that Part alone, without affecting other
Parts; and may be corrected at any Time independent of the reft.
This Way of carrying on a geometrical Survey, whether inland or
maritim, will appear evidently to be much more perfect than thofe
commonly practifed; and to furpafs them, not only in Accuracy,
but in Expedition; and is the only Method from which an exact
extenfive Survey is to be expected. Other Methods of furveying are
defective either in their Foundation, or their Procedure, or in both :
and their Errors, generally, flip infenfibly into all the Parts of a
Survey, increafing as it goes on. Thence it is, that fo few Surveys
have been continued beyond the Extent of a large Bay, or River;
that the Errors of former Draughts are not to be corrected without
an intire new Survey; that fome Places have been furveyed again
and again, yet in Procefs of Time are found to require it anew;
and that fo few Draughts are to be met with that anfwer the End

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for which they are intended, viz. to direct Ships into fafe Anchorage without a Pilot. The Defign of the following Sheets is, to explain and recommend to more general Practice, the ftafimetric Manner of furveying; to render future Draughts of the Sea-coaft more complete and ferviceable than what have been hitherto offered to the Public; and to direct fea-faring Gentlemen, who have gone through a Courfe of Navigation, how to make ufeful Draughts of fuch Bays or Harbours as they may occafionally be in; and by Means of fuch Inftruments *only* as Seamen are commonly provided with.

USEFUL

	Inches			Feet
The English Foot is	12	A Yard	- - -	3
The Paris Foot	12,788	A Fathom	- - -	6
The Amsterdam Foot	11,172	A Cable-Length 100 Fathom, or 600		
The Danish great Foot	12,465			
The Swedish Foot	11,692			

	Yards
An English Statute Mile is - - - -	1760
A Geometrical Mile - - -	2038,6
A League, 3 Geometrical Miles - - -	6115,8
A French League, called Lieu legale - -	3996,46
A Sea League of France - - - - -	6394,375
The Dutch League of 18000 Rhinland Feet - -	6186
The common German Mile of 22800 Rhinland Feet	7829,666
The League of Sweden 30000 Rhinland Feet -	10310

	English Miles
A Degree of the Meridian in Britain -	69,5
A Degree at the Equator - - -	67,75
A Degree at the Pole - - -	70,1
The Chord of one Degree of the Meridian	69,150
The Chord of half a Degree - -	34,960
The Diameter of the Earth - -	7910, or, 41798117 Feet

The Sun's Semidiameter about the Equinoxes is -	16′
About the Middle of Summer is - - -	15′, 45″
About the Middle of Winter is - - - -	16′, 15″
The Sun's greatest Declination is - - -	23°, 28′, 9″

Geometrical Miles in a Degree of Longitude.

Deg. of Lat.	0	5	10	15	20	25	30	35	40
Miles and Parts.	60	59,77	59,09	57,95	56,28	54,38	51,96	49,15	45,96
Deg. of Lat.	45	50	55	60	65	70	75	80	85
Miles and Parts.	42,43	38,57	34,41	30,00	25,36	20,52	15,53	10,42	5,23

MARITIM

MARITIM SURVEYING.

PART I.

Containing the geometrical Principles and other Pre-requisites of Surveying.

CHAP. 1. Of the Principles and Pre-requisites in general. 2. Trigonometrical Solutions. 3. Longimetrical Operations and Problems. 4. Examination of Instruments. 5. Meridional Problems, and the Variation of the Needle.

C H A P. I.

Of the geometrical Principles, and other Pre-requisites of Surveying, in general.

BEFORE one undertakes a geometrical Survey of the Sea-coast, it will be found of Advantage to have learned Drawing; at least so much of it as to be capable of shading with Indian-ink, or etching with a Pen, Hills, Rocks, Cliffs, miniature Buildings, and the Coast-line of a Map; of sketching, from Nature, the Out-lines of them; and of taking distant Views of the Land, from Sea. This can only be attained by long Practice, together with a few Instructions from a Drawing-master. A Surveyor who is not capable of sketching readily, and shading with some Neatness, ought to have a Drawer along with him for that Purpose.

He should also be acquainted with the Elements of Geometry and Astronomy; at least with as much as is taught in a common Course of Navigation; so as to be ready in protracting Lines and Angles, and calculating the Cases

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of

of plain and fpherical Trigonometry by logarithmic Tables, when the Pro-
portions are ftated; and applying the former to the Menfuration of Dif-
tances, and the latter to that of fpherical Arcs and Angles; of taking the
Altitude of the Sun, or a Star, with a Quadrant on Sea and Land, and
from thence finding the Latitude of a Place; and of knowing by the Eye
a few of the fixt Stars, efpecially fuch as are near the elevated Pole.

He fhould alfo make himfelf acquainted with the Structure of the prin-
cipal inftruments ufed in furveying; fuch as the Theodolite, the aftronomical
Quadrant, and Hadley's Octant, or Sextant; and underftand how to ex-
amin, adjuft, and obferve with them. If he is defective in any of the above
Particulars, his Operations and Obfervations will be tedious and inaccurate,
or his Draughts void of Neatnefs and Elegance.

C H A P. II.

Trigonometrical Solutions.

THE Cafes in plain Trigonometry that occur in furveying, are the
four following.

1. Having two Angles of a Triangle, and a Side oppofite to one of them,
to find another Side; ufe the following Proportion.
    As the Sine of the Angle oppofite to the Side given,
    Is to the Sine of the Angle oppofite to the Side required;
    So is the Side given,
    To the Side required.

2. Having two Sides and an Angle oppofite to one of them, to find an-
other Angle; ufe the following Proportion.
    As the Side oppofite to the Angle given,
    Is to the Side oppofite to the Angle required;
    So is the Sine of the Angle given,
    To the Sine of the Angle requir'd.

In

In the above Cafes, it will affift the Memory to obferve, that when a Side is wanted, the Proportion muft begin with an Angle; and when an Angle is wanted, it muft begin with a Side.

3. Having two Sides of a Triangle, and the included Angle, to find the other Angles, and Side; ufe the following Proportion.

As the Sum of the two given Sides,
Is to their Difference,
So is the Tangent of half the Sum of the two unknown Angles,
To the Tangent of half their Difference.

Then half their Difference (thus found) added to half their Sum, will be the greateft of the two Angles fought; which is the Angle oppofite to the greateft Side. If the third Side is wanted, it may be found by Solution I. for two Angles are known, and a Side oppofite to one of them.

4. The three Sides of a Triangle being given, from thence to find the Angles; proceed by the following Steps and Proportions.

PLATE I. FIG. I.

1. Let A B C be the Triangle: make the longeft Side A B the Bafe: from C, the Angle oppofite to the Bafe, let fall the Perpendicular C D, on A B; which will divide the Bafe into two Segments A D and D B. Then,

2. Find the Difference of A D and D B, by the following Proportion.
As the Bafe A B,
Is to the Sum of the other Sides (A C + B C)
So is the Difference of the Sides (A C — B C)
To the Difference of the Segments of the Bafe (A D — D B.)
Half the Difference of thefe Segments (thus found) added to the half of A B, gives the greateft Segment A D; or fubtracted, leaves the leaft D B. Then,

3. In the Triangle A D C, by Sol. 2. find the Angle A C D: for the two Sides A D and A C are known, and the right Angle at D is oppofite to one of them. The Complement of A C D is the Angle A. Then,

4. In

4. In the Triangle A B C, you have two Sides A B and B C, and the Angle at A oppofite to one of them; from thence (by Sol. 2.) find the Angles C and B required.

CHAP. III.

Longimetrical Operations and Problems.

SEC. I. OPERATION I.

How to proceed in meafuring a ftraight Line.

BEFORE any Diftance can be meafured trigonometrically, the Length of one ftraight Line, or Diftance, muft be firft found mechanically, by meafuring it on a Plane with a Pole or Chain. And as this Menfuration is more or lefs exact, fo will all the other Diftances be that are deduced from it. The utmoft care therefore ought to be taken in meafuring this firft Diftance, or fundamental Bafe-line, exactly; and all Sources of Error in the Operation guarded againft, as much as poffible. The following Directions will be found fufficiently exact for any Survey.

1. Prepare a Meafuring-pole 20 or 30 Feet long, precifely meafured, fquare at one End, and a firm oblong Ring at the other; or a Chain 60 Feet long: three Poles, each 10 Feet long, with white, or dark-coloured Flags, to be tied to their Tops, according as they may appear on the Land, or between you and the Sky: 12 Poles, each 5 or 6 Feet long, with a fmall Flag on every fourth Pole: four iron Reels and Stakes, fuch as Gardners ufe, with about 200 Yards of fmall Cord to each Reel: 20 cylindrical Pins for counting the Number of Poles, or Chains, as you are meafuring, each about 8 Inches long, and fharpened at the Point for piercing the Ground eafily: two wide-mouth'd Canvas-pockets to carry the Pins in, with Strings for tying one of them round the Middle of each of the Meafurers.

2. Pitch on a level Plane, as long as can be had; fuch as a fmooth Sand, a Salt-marfh, or (which is by far the beft) a frozen Lake.

In this Plane, chufe fuch a Direction for the Line to be meafured, as that the principal Objects whofe Diftances are required, may be feen from both

its

its Extremities; and that the greateſt Angle any of theſe Objeƈts make with it, may not be too oblique (or not above 140 Degrees :) and, if convenient otherwiſe, let one End of this Line run direƈtly on ſome remarkable Part of a remote Objeƈt; ſo that, at the other End, its Direƈtion may be readily found, at any time, by that Objeƈt.

4. At each End of the Line to be meaſured, ſet up a long Pole, with a white Flag flying at the Top of that which appears on the Land; or a dark Flag on that which appears between you and the Sky, or on white Sand; ſo that they may be eaſily ſeen from each other: about the Middle between theſe two ſet up the other long Pole, exaƈtly in a Line with them: and in a right Line between theſe three ſet up ſhorter Poles all along, about 200 Yards aſunder, with a Flag at the Top of every fourth or fifth Pole.

5. Stretch a Line, or Cord, from Pole to Pole, touching the ſame Side of each Pole as it paſſes them.

6. Immediately before you begin meaſuring along theſe Lines, try the Length of your Meaſuring-pole, or Chain, with a Six-foot mahogany Rod divided into Feet; one of the Feet into Inches and Tenths of an Inch; the Thickneſs of the Wire of the Ring at the End of the Meaſuring-pole is not to be included in its Length: Count alſo the Pins, put them in the Canvas-pocket, and give them all to the Leader, or foremoſt Man, that carries the Pole.

7. Lay the Meaſuring-pole exaƈtly along the Cords, with the Ring at the Part you begin the Meaſurement from, and its Square-end foremoſt; at the Square-end, juſt touching it in the Middle, the Leader is to ſet down a Pin, and to go on with the Pole until the Follower (or he who carries the Ring-end) comes up to that Pin, and puts the Ring round it; then the Leader laying the Pole exaƈtly along the Cord, muſt thruſt down another Pin at the Square-end. When that is done, he calls to the Follower, who muſt take up the Pin in the Ring, put it into the Canvas-pocket which is tied round his Middle, and go on to the next Pin, putting the Ring round it; and when the Leader has put down another Pin, and called, then the Follower muſt take his Pin up, put it in the Pocket, and go on to the next,

as

as before; proceeding in this manner till all the Pins are put down by one, and taken up by the other. Then leaving the Meafuring-pole exactly placed along the Cord, without a Pin at any of its Ends, let the Pins be counted over, to be fure that none are wanting, and the Number marked down on Paper, and all of them given back to the Leader, to begin anew, by placing a Pin at his End of the Pole, as it lies along the Line, which the Follower is to put his Ring round, and take up as before, and fo go on till the whole Diftance propofed is meafured.

The Ufe of the Ring at one End of the Pole, inftead of laying one Pole at the End of another, is, to confine the Meafurers to more Exactnefs; which will be found a neceffary Precaution for a Surveyor.

A Chain is not fo exact for meafuring with, when great Precifion is required, as a Pole; but is much more conveniently carried; and, when Care is taken to lay it ftraight, and to prevent the Links from riding on one another, it will be found fufficiently exact on moft Occafions.

8. If the Sand meafured has a fenfible and gradual Declivity, as from High-water Mark to Low-water, then the Length meafured may be reduced to the horizontal Diftance (which is the proper Diftance) by making the perpendicular Rife of the Tide, one Side of a right-angled Triangle, the Diftance meafured along the Sand the Hypothenufe, and from thence finding the other Side trigonometrically, or by Protraction on Paper; which will be the true Length of the Bafe-line. If the Plane meafured is on the dry Land, and there is a fenfible Declivity there, the Height of the Defcent muft be taken by a Spirit-level, or by a Quadrant, and that made the perpendicular Side of the Triangle.

If, in a Bay, one ftraight Line of a fufficient Length cannot be meafured, let two, or three Lines, forming Angles with each other, like the Sides of a Polygon, be meafured on the Sand along the Circuit of the Bay: thefe Angles carefully taken with a Theodolite, and exactly protracted, or calculated, will give the ftraight Diftance between the two fartheft Extremities of the firft and laft Line. In taking the Angles, let the Center of the Theodolite be placed exactly over the Point where the two Sides meet, by a Plummet,

met,

met, or by dropping a Stone down ; and let Poles be set straight up in the Ends of the two Sides that form the Angle: for a small Error in the Angle, especially in the first, will often make a considerable Error in the Distance deduced from it.

Some Surveyors measure their Distances by a *Wheel*.   But as a Wheel has a small serpentine Motion from Side to Side, occasioned by the Steps of the Person that leads it ; and besides, traces all the little Inequalities of the Ground, which, however smooth to Appearance, no Plane (if it is not smooth Ice) is quite free from ; this way of measuring cannot be reckoned sufficiently exact for a fundamental Base-line.   Much less is any Distance measured by a Line, or Rope, to be esteemed sufficiently exact : for that will lengthen more, or less, by the Strength applied in stretching it along the Ground ; and likewise lengthens, or shortens, by the various Degrees of Heat, or Moisture in the Air, or on the Plane measured.

OPERATION II.

How to measure a straight Line on the Surface of the Sea.

First, prepare a Measuring-line of strong Cord, two or three hundred Yards in Length, with small Pieces of Cork of equal Thickness made fast to it at small Distances, all along, like a Fishing-net, so that it may float straight on the Surface of the Water : if the Line has been well stretched, or much used before, it is the better : also prepare two Ropes somewhat longer than the greatest Depth of the Water to be measured, with a Pig of Lead or Iron Ballast (which we shall call an Anchor) 50 or 60 Pounds-weight, tied by the Middle to one End of each Rope, that when it is at the Bottom it may be able to anchor a Boat, and bear to be stretched straight without shifting the Place of the Anchor.   Let the Measuring-line be thoroughly wet immediately before you begin to use it, and then stretched on the Water close by the Shore, and its Length measured there with a Pole.   Then, in the Direction intended to be measured, take two remarkable sharp Objects on the Land in a Line, one near the Shore, the other as far up in the Country as you can : if such are not to be had, place Buoys on the Water at proper Distances in that Direction.

2. Take the Objects, or Buoys, in a Line, and holding one End of the Meafuring-line faft on the Shore, carry out the other in a Boat, in that Direction, till it is ftretched ftraight at its full Length by one Man in the Boat, and exactly at the End of the Line let another Man drop the Anchor, which will mark one Length of it. There keep the Boat, and the End of the Meafuring-line, clofe to the Anchor-rope, drawn right up and down, till another Boat takes in the other End which was on the Shore, and rows farther on, and lays it ftraight in the Direction of the Land-marks, or Buoys, and there drops another Anchor, which will mark the fecond Length of the Meafuring-line. Go on thus till the whole propofed Diftance is meafured ; and immediately after let the Meafuring-line be again meafured with a Pole on the Water near the Shore, as at firft, and if the Lengths differ, take the mean between them for the true Length. It is obvious, that to meafure with any Exactnefs this way, the Sea muft not only be fmooth, but void of a Swell, and of all Stream of Tide ; either of which will hinder the Line to lie ftraight. This Method of meafuring a ftraight Line may be convenient on fome Occafions ; and if Care is taken to keep the Anchor-rope right up and down when the Meafuring-line is applied to it, will be found fufficiently exact for many Purpofes, but not for a fundamental Bafe-line from which other Diftances are to be deduced.

There is another way of meafuring a ftraight Line, mechanically, on the Sea, which is fo well known to Seamen, that it is needlefs to defcribe it particularly here : and that is, by heaving the Log over a Ship's Stern while fhe is under fail, and obferving how many Knots of the Log-line runs out in half a Minute ; for the Line is fo divided that the Ship will run (or, is fuppofed to run) fo many miles in an Hour, in a ftraight Courfe ; and twice as much in two Hours, and fo on. But this Conclufion is founded on three Suppofitions, neither of which are certain, viz. That the Log remains in the fame Place during the whole half Minute that the Line is running out from the Ship's Stern ; that the Ship continues to fail with the fame Velocity, and alfo in the fame Direction, during an Hour, or two, that fhe did during the half Minute : the contrary of which is more likely in moft Cafes. For the Log-line may fhrink, or ftretch, while it is running out ; or may drag after the Veffel by the Weight of the Line, or by not running eafily and readily off the Reel ; the Swell of the Sea may alter the Place of the Log ; and

Currents

Currents or Streams of Tide, ſtronger or weaker below the Surface than at it, an unſteady Helm, Lee-way, and varying Winds may change the Direction, or Celerity of the Ship's Motion; for neither of which can any certain Allowance be made. This way, therefore, of meaſuring a ſtraight Line, or Diſtance, is not to be depended on as exact: but is mentioned here, becauſe Rocks, Shoals, or Iſlands ſometimes lie ſo far from the Coaſt, that there is no other way of forming any Notion of their Diſtance. If any ſuch Diſtance is to be meaſured after this manner, let the Log-line be thoroughly wet when it is meaſured; let the Length between each Knot be 51 Feet, which is the Hundred-and-twentieth Part of a geometrical Mile, as half a Minute is $\frac{1}{120}$th Part of an Hour; chuſe Neap-Tide, as much ſlack Water as can be got, and a moderate Breeze of following Wind; let the Line be run off the Reel ſo as never to be ſtretched quite ſtraight; and if the Half-minute is meaſured by a Watch that ſhews Seconds, rather than by a Glaſs, it will generally be more exact. Perhaps one Second ſhould be allowed for the Loſs of Time in calling out at the Beginning, and ſtopping it at the End of the Time; except the Perſon who holds the Watch can contrive to obſerve the going out of the red Rag at the Beginning, and alſo to ſtop the Line himſelf at the End of the Time; which does not ſeem a difficult Matter.

OPERATION III.

To find the Diſtance of two Places, by the Flaſh and Report of a Gun.

Stand in one of the Places with a Stop-watch in your Hand; the Watch ſtopt with the Second-hand at 60, and your Finger at the Stopper: let a Gun be fired at the other Place, at an appointed time. When you ſee the Flaſh, or Smoke, that inſtant ſet the Watch agoing; and immediately as you hear the Report, ſtop it; and it will ſhew the Number of Seconds of Time between the Flaſh and Report. By that Number multiply 1142, and the Product will be the Diſtance of the two Places in Feet: for Sound is found to move 1142 Feet in a Second.

This Operation ſhould be repeated two or three Times, for more Certainty; and the exacteſt of them, if it is certainly known, fixed on for the true Time:

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or

or a Mean of all, if no Diftinction can be made. It fhould alfo be performed when there is little Wind ; for a Breeze of Wind, with or againft the found, is found to quicken or retard it a little. It is likely that fome fmall Variation may alfo arife from different Degrees of Denfity, and Elafticity in the Air ; the former retarding, and the latter accelerating Sound. But this has not yet been afcertained by Experiments.

By this way of meafuring Diftances, fuch as are not more than two Miles cannot be reckoned exact ; becaufe of the Difficulty of fetting the Watch agoing, and ftopping it at the precife Times ; which may caufe an Error of, at leaft, one Quarter of a Second or 90 Yards, which is too much in fo fhort a Diftance. If the Diftance is four Miles, or more, it may be reckoned fufficiently exact for ordinary Purpofes. I incline to think, if half a Second is allowed for the Time loft in ftopping the Watch and fetting it agoing, that, after a little Practice, one may meafure two Miles pretty exactly by this Method ; provided the State of the Air is fuch as it was when the Experiments for determining the Velocity of Sound were made.

It is to be wifhed that thofe Experiments were repeated over again by fome careful Perfon, who would attend to the feveral Circumftances of the Air and Wind that might affect the Celerity of Sound, and publifh the Effect of each, for the Conveniency of Surveyors, and the farther Satisfaction of the Curious.

SECTION II.

Longimetrical Problems.

PROB. I.

Having the Length of a Bafe-line X Y, *to find the Diftance of two, or more remote Objects* A, B *and* C, *from it, and from each other.*

PLATE I. FIG. II.

BY PROTRACTION.

With a Theodolite, or Hadley's Quadrant, at one End of the Bafe-line X, take the Angles Y X A, Y X B, Y X C ; at the other End Y, take the

Angles

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Angles X Y A, X Y B, X Y C, and write them down in a Book.   Then draw a Line on the Paper of a sufficient Length, and in a convenient Position: pitch on any convenient Part of that Line for the Point X; and taking the Length of X Y from a Scale of equal Parts, set it off from X to Y: at X draw the observed Angle Y X A; and at the other End Y, draw the observed Angle X Y A, and the Interfection of thefe two Lines will be the Point A; and X A, measured on the Scale from which X Y was taken, will be the Diftance of A from X.   In the fame manner the Points B, or C, may be determined; and the Length of A B, or B C, measured on the Scale, will give the Diftance of A from B, or B from C: and fo for any other Points whofe Diftances are required, whether they lie on one Side of the Bafe-line or the other.

Let it be obferved, that if X Y is drawn on the Paper according to its magnetic Direction, then the Points A, B, and C, will likewife be in their magnetic Directions from X and Y, and from each other.

To render protracted Diftances more exact, the Length of the Bafe-line fhould not be lefs than one feventh, or one eighth Part, of the Diftance of the fartheft Object; none of the Angles fhould be too oblique, or above 140 Degrees; the Protractor fhould be at leaft 12 Inches Diameter, and each Degree fubdivided into four Parts; or more minutely by an Index with a vernier Scale on it.

BY CALCULATION.

In the Triangle X Y A there are given the meafured Side X Y, and the obferved Angles Y X A and X Y A, and therefore the Angle Y A X, their Compliment to 180°; that is, two Angles and a Side oppofite to one of them: therefore, (by Trigon. Sol. 1. Page 2.) the Side X A may be found. In the fame manner, in the Triangle X Y B, may X B or Y B be found. Then, in the Triangle A X B, there are given the two Sides X A and X B, and the included Angle (the Difference of the obferved Angles Y X A and Y X B;) hence A B may be found, by Trigon. Sol. 3. Page 3.

PROB. II.

To find the Diſtance of two Places, when the Latitudes, their Bearing by the magnetic Needle, and the Variation of the Needle are known.

PLATE I. FIG. III.

BY PROTRACTION.

1. Draw the Line X A right up and down on the Paper, for the magnetic Meridian.

2. Pitch on a convenient Point X in that Line, to repreſent one of the Places ; and at the Point X make the Angle A X B equal to the Variation, and on the Eaſt-ſide of X A, if the Variation is Weſt ; but on the Weſt-ſide of it, if the Variation is Eaſt ; and X B will be the true Meridian.

3. At X make the Angle A X Y equal to the magnetic Bearing of the other Place from X.

4. Take from a Scale of equal Parts the Difference of Latitude of the two Places in geometrical Miles, and ſet it off on the true Meridian from X to B.

5. At B raiſe a Perpendicular B Y cutting X Y in Y ; and the Point Y will be the other Place ; and X Y, meaſured on the Scale, will be the Diſtance of the two Places in geometrical Miles.

If their Diſtance is wanted in Engliſh Miles, ſay, as 60 is to 69, 5 ſo is their Diſtance in geometrical Miles, to their Diſtance in Engliſh Miles : for 69 and a half Engliſh Miles make 60 geometrical Miles.

BY CALCULATION.

In the right-angled Triangle Y B X, there is given the Angle Y X B, in this Caſe, equal to the Bearing of Y and Variation of the Needle together;

and

and therefore the Angle at Y is alfo known; and the Side X B oppofite to one of them: hence (by Trigon. Sol. 1.) X Y is found.

In this Problem, the greater the Difference of Latitude of the two Places is, and the nearer they are to the fame Meridian, their Diftance will come out the more exact. For, an Error of half a Minute can hardly be avoided in the Latitudes, though taken with the beft portable Quadrant; nor an Error of 15 Minutes, fometimes, in the Bearing of Y from X, though taken with the beft Needle: more efpecially as the Polarity of Needles is found to vary, in the fame Place, above 20 Minutes in a Day, according to the State of the Atmofphere, as is thought. To be fufficiently exact, therefore, the Difference of Latitude of the Places fhould be no lefs than 15 Miles, and the Angle B X Y no greater than 45 Degrees.

The Accuracy of this Problem depends chiefly on the Accuracy of the two Latitudes: for fuppofing the Needle to be twenty Minutes wrong, it will not occafion an Error of a Quarter of a Mile in a Diftance of thirty Miles, if the Interfection of the Bearings is not oblique: and therefore, if the Quadrant with which the Latitudes are found, and the Obfervations likewife, are not known to be good, the Diftance deduced from them is not to be depended on as exact. In calculating the Latitudes by the Sun's Meridian Altitude, remember to make the proper Allowance for the Sun's Semidiameter, (at a Medium 16', as in the Table, Page 17,) the Refraction, Variation of the Sun's Declination for the Time between your Meridian and the Meridian of the Tables; and if the Altitude is taken with Hadley's Quadrant, by the vifible Horizon, make Allowance alfo for the Depreffion of the Horizon, or Altitude of the Eye above the Surface of the Sea; according to the Table in Page 18.

Here it may be obferved, that the Diftance between X and Y, thus found, is the Length of an Arc of a great Circle of the Earth between thefe two Stations, and not the ftraight Line, or fhorteft Diftance. The Chord of that Arc is the true Diftance to be ufed in Surveying. Therefore inftead of X Y meafured by two Latidudes, take its Chord, which is twice the Sine of half the Arc. The Proportions between the following Arcs and their Chords were found by the Tables of natural Sines by faying, As

the

the Radius of the Tables, is to the natural Sine of half the given Arc, fo is the Radius of the Earth to a fourth Number; which doubled, is the Chord required. If X Y therefore is found by two Latitudes to be 69½ English Miles, the Chord of that Arc, or fhorteſt Diſtance between X and Y is only 69 Miles and 150 Yards: if the Arc is 34¾ Miles, its Chord is 34½ Miles and 80 Yards: if the Arc is 20 Miles, its Chord will be 19¾ Miles and 264 Yards nearly. If the Arc meaſured is leſs than twenty Miles, its Chord may be reckoned the ſame with the Arc.

If, in Practice, it ſhall happen that Y cannot be ſeen from X; or that, becauſe of their Diſtance, both Points cannot be included in the ſame Draught; in theſe Caſes, to avoid the Trouble and Loſs of Time in finding the Latitude of another Place inſtead of X, pitch on ſome other Station nearer Y, as S, whoſe Diſtance and Direction from X is determined on the Draught, and where Y can be ſeen: find its Latitude, by letting fall the Perpendicular S b on the true Meridian drawn through X; and b X meaſured on the Scale and reduced to geometrical Miles, will be the Difference of Latitude between X and S: which added to, or ſubtracted from, the Latitude of X (as S is northward or ſouthward of it) will be the Latitude of S. Then, having the Latitude of S and of Y, find their Diſtance, as before directed.

To find how much the Sun's Declination, at any Place, differs from the Declination in the Table.

Judge, as near as you can, what the Difference of Longitude is, in Time, between the Place of Obſervation, and the Place for which the Table of Declination is calculated. Then, ſubtract the Declination for the Day of Obſervation, and for the Day next following, from each other, and the Remainder will be the Variation of Declination for one Day, or 24 Hours; and allow a twenty-fourth Part of that Variation for every Hour between your Meridian and the Meridian of the Table of Declination. For Example: ſuppoſe the Variation of the Sun's Declination in 24 Hours, is found by the Table to be ten Minutes; and the Longitude of the Place of Obſervation, from the Place for which the Table of Declination is calculated, is 45 Degrees, or 3 Hours; then ſtate the Proportion thus,

As

As 24 Hours : is to 10′ : : fo is 3 Hours : to 1′, 15″. Which 1′, 15″ is to be added to, or fubtracted from, the Declination in the Table, according to the Circumftances following.

When the Sun's Declination is increafing : if you are eaftward of the Meridian of the Table, the Remainder muft be fubtracted from the Declination in the Table : but if you are weftward of the Meridian of the Table, it muft be added, to give the Sun's Declination at the Place of Obfervation.

When the Sun's Declination is decreafing : if you are eaftward of the Meridian of the Table, the Remainder muft be added to the Declination in the Table : if you are weftward, it muft be fubtracted from it, to give the Declination at the Place of Obfervation.

Within three, or four, Days of the Solftices, an Error of 30, or 40 Degrees in the Longitude of the Places, will make no fenfible Error in the Sun's Declination : but when the Sun is within 10 Degrees of the Equinoxes, to be fufficiently exact in the Declination, the Longitude fhould be known to half an Hour, or 8 Degrees.

A fure and ready Way to find, whether the Sun's Declination, or Zenith Diftance is to be added or fubtracted, to produce the Latitude.

Let it be obferved, that if the Sun's Place in the Eclyptic is transferred to the Earth, or, marked by a Point on the Meridian of a Place ; then, the Sun's Meridian Zenith Diftance, obtained by the Quadrant, is equal to the Diftance of that Point from the Place of Obfervation : and therefore, when the Diftance of the Sun (or the Point which reprefents it) from the Equator, is known, the Diftance of the Place of Obfervation from the Equator will likewife be known.

PLATE I. FIG. IV.

If therefore a Circle N E P Q is made by Hand, reprefenting a Meridian on the Earth, and a Line E Q, for the Equator, drawn through the Middle of it ; then a Point S, reprefenting the Sun's Place, marked by Guefs on the

Circle ;

Circle; but on the North, or South Side of the Equator-line, as the Sun's Declination is North or South; and another Point Z, for the Place of Observation, North from S, if the Sun is South at Mid-day; but South of S, if the Sun is North at Mid-day: then by infpecting that Figure, it will be eafy to fee whether the Declination, or Zenith Diftance, is to be added or fubtracted from each other, to give Z E, the Latitude, or Diftance of the Place from the Equator. In this Cafe, it is obvious, that the Declination S E muft be added to Z S the Zenith Diftance, to give Z E the Diftance of the Place from the Equator. Again, let s be the Sun's Place, then Z s is the Zenith Diftance, from which s E muft be fubtracted to give Z E the Diftance from the Equator. Again, if s is the Sun's Place, and z the Place of Obfervation, the Sun being fuppofed North at Mid-day; then z s is the Zenith Diftance, to which s E, the Declination, muft be added, to give z E, the Diftance of z from the Equator. If z falls between s and E, then the Zenith Diftance muft be fubtracted from the Declination to give the Latitude: as will be manifeft by marking the Points properly on the Figure.

PROB. III.

To find the Latitude of a Place which is inacceffible.

Firft find the Variation of the Needle; then, by the Direction of the Needle, pitch on a convenient Place which bears due Eaft, or due Weft, from the inacceffible Place whofe Latitude is required; there find the Latitude, and that will be the Latitude of the other likewife: for both are in the fame Parallel.

The nearer the Place of Obfervation is to the other, the more exactly will the Latitudes agree; becaufe they will be lefs affected by any Inaccuracy in the Bearing by the Needle.

A TABLE

A TABLE of the Refraction of the Heavenly Bodies in Altitude.

App. Alt.	Refrac.	App. Alt.	Refrac.	App. Alt.	Refrac.	App. Alt.	Refrac.	App. Alt.	Refrac.	App. Alt.	Refrac.
° '	' "	° '	' "	° '	' "	° '	' "	° '	' "	° '	' "
0. 0	33. 0	3. 30	13. 6	7. 40	6. 45	13. 0	4. 3	27. 0	1. 51		
5	32. 10	3. 40	12. 40	7. 50	6. 37	13. 20	3. 57	28.	1. 47		
10	31. 22	3. 50	12. 15	8. 0	6. 29	13. 40	3. 51	29.	1. 42		
15	30. 35	4. 0	11. 51	8. 10	6. 22	14. 0	3. 45	30.	1. 38		
20	29. 50	4. 10	11. 29	8. 20	6. 15	14. 20	3. 40	31.	1. 35		
30	28. 22	4. 20	11. 8	8. 30	6. 8	14. 40	3. 35	32.	1. 31		
32	28. 5	4. 30	10. 48	8. 40	6. 1	15. 0	3. 30	33.	1. 28		
36	27. 30	4. 40	10. 29	8. 50	5. 55	15. 30	3. 24	34.	1. 24		
40	27. 0	4. 50	10. 11	9. 0	5. 48	16. 0	3. 17	35.	1. 21		
50	25. 42	5. 0	9. 54	9. 10	5. 42	16. 30	3. 10	36.	1. 18		
1. 0	24. 29	5. 10	9. 38	9. 20	5. 36	17. 0	3. 4	37.	1. 16		
1. 10	23. 20	5. 20	9. 23	9. 30	5. 31	17. 30	2. 59	38.	1. 13		
1. 20	22. 15	5. 30	9. 8	9. 40	5. 25	18. 0	2. 54	39.	1. 10		
1. 30	21. 15	5. 40	8. 54	9. 50	5. 20	18. 30	2. 49	40.	1. 8		
1. 40	20. 18	5. 50	8. 41	10. 0	5. 15	19. 0	2. 44	41.	1. 5		
1. 50	19. 25	6. 0	8. 28	10. 15	5. 7	19. 30	2. 39	42.	1. 3		
2. 0	18. 35	6. 10	8. 15	10. 30	5. 0	20. 0	2. 35	43.	1. 1		
2. 10	17. 48	6. 20	8. 3	10. 45	4. 53	20. 30	2. 31	44.	59		
2. 20	17. 4	6. 30	7. 51	11. 0	4. 47	21. 0	2. 27	45.	57		
2. 30	16. 24	6. 40	7. 40	11. 15	4. 40	21. 30	2. 24	46.	55		
2. 40	15. 45	6. 50	7. 30	11. 30	4. 34	22. 0	2. 20	47.	53		
2. 50	15. 9	7. 0	7. 20	11. 45	4. 29	23. 0	2. 14	48.	51		
3. 0	14. 36	7. 10	7. 11	12. 0	4. 23	24. 0	2. 7	49.	49		
3. 10	14. 4	7. 20	7. 2	12. 20	4. 16	25. 0	2. 2	50.	48		
3. 20	13. 34	7. 30	6. 53	12. 40	4. 9	26. 0	1. 56	51.	46		
52.	44	59.	34	67.	24	75.	15	83.	7		
53.	43	60.	33	68.	23	76.	14	84.	6		
54.	41	61.	32	69.	22	77.	13	85.	5		
55.	40	62.	30	70.	21	78.	12	86.	4		
56.	38	63.	29	71.	19	79.	11	87.	3		
57.	37	64.	28	72.	18	80.	10	88.	2		
58.	35	65.	26	73.	17	81.	9	89.	1		
		66.	25	74.	16	82.	8	90.	0		

D   A TABLE

A TABLE of the Depreffion, or Dip, of the Horizon of the Sea.

Height of the Eye above the Sea in Feet.	Depreffion of the Horizon of the Sea.		Height of the Eye above the Sea in Feet.	Depreffion of the Horizon of the Sea.		Height of the Eye above the Sea in Feet.	Depreffion of the Horizon of the Sea.	
	'	"		'	"		'	"
1	0.	57	12	3.	18	35	5.	39
2	1.	21	14	3.	34	40	6.	2
3	1.	39	16	3.	49	45	6.	24
4	1.	55	18	4.	3	50	6.	44
5	2.	8	20	4.	16	60	7.	23
6	2.	20	22	4.	28	70	7.	59
7	2.	31	24	4.	40	80	8.	32
8	2.	42	26	4.	52	90	9.	3
9	2.	52	28	5.	3	100	9.	33
10	3.	1	30	5.	14			

PROB. IV.

Having the Diftances of three Points, A, B and C, either in a ftraight Line, or forming a Triangle; at any Station S, without the Triangle, to find its Diftance from thefe Points.

PLATE I. FIG. V.

BY PROTRACTION.

At S, with a Theodolite, or Hadley's Sextant, take the Angles A S C and C S B: then, making A B (the Side which fubtends the greateft Angle, and is oppofite to the middlemoft Point) the Bafe; at B, make the Angle A B D equal to the Angle A S C, and lying on that Side of A B which is fartheft from S; and at A, make the Angle B A D equal to C S B, interfecting A D in D; draw a Circle paffing through the three

Points

Points A, D, B, and it will alſo paſs through S : draw out the Line C D, and it will cut the Circle in S, the Point of Station required.

Demonſtration. The Angles A S D and A B D are equal, for they ſtand in the ſame Segment A S B D (Eucl. B. III. Prop. 21.) A S D is therefore equal to the firſt obſerved Angle. In the ſame manner, B S D and B A D are equal, for they ſtand in the ſame Segment D A S B ; and D S B is therefore equal to the other obſerved Angle ; and S the Point of Station, and S A, S C, S B, the Diſtances required.

BY CALCULATION.

1. In the Triangle A B C, the Sides being known, the Angles are found by Trig. Sol. 4. Page 3.

2. In the Triangle A B D, the Side A B is given by Suppoſition ; and the Angles D A B and D B A equal, reſpectively, to the correſponding obſerved Angles ; therefore the Angle at D is alſo known : from thence (by Trig. Sol. 1.) find the Side A D. Then,

3. In the Triangle C A D, the Sides C A and A D are known, and the included Angle C A D (which is what B A D wants of B A C) from thence (by Trig. Sol. 3.) find A C D. Then,

4. In the Triangle A S C, two Angles A S C and A C S, and the Side A C oppoſite to one of them, are known; from thence (by Trig. Sol. 1.) A S may be found. In the ſame manner may S B or S C be found.

If the Point C is on the other Side of A B, towards S, or in the Line A B, it is obvious that S may be found in the ſame manner ; the ſame Pro-traction, and Calculation, ſerving for each of theſe Caſes.

F I G. VI.

If it ſhall happen that the Points C and D fall ſo near each other, that in protracting, C D is produced with Uncertainty, which will happen

when

when the Point C lies beyond A B; and the obferved Angle A S C is nearly equal to the Angle A B C, and the other obferved Angle C S B is nearly equal to the Angle C A B. In which Cafe take the Point C on the Side of A B which is next to S, as at K: or, fhift your Station nearer to, or farther from C, and find the Pofition of that Station, and then its Diftance from S. Or, on C B, make the Angle C B D equal to the obferved Angle A S C, and the Angle B C D equal to the Supplement to 180° of both the obferved Angles A S B; then the Interfection of thefe Sides will be the Point D: draw a Circle paffing though the Points B, C, D, and A D produced, will cut that Circle in S, the Point of Station required. For,

B S D C being a quadrilateral Figure infcribed in a Circle, B S D is the Supplement of B C D to 180° (by Eucl. B. III. Prop. 22.) and by Con-ftruction equal to the two obferved Angles: and A S C and D B C being equal, as ftanding on the fame Arc D C; A S C muft be the firft obferved Angle, and C S B (the Remainder of A S B) the other; and S therefore the Point of Station.

Here it may be obferved, that the Diftance of an Object found in this manner by Hadley's Sextant, is the real aerial Diftance in a ftraight Line from the Eye to the Object; but it is the level Diftance that is neceffary in furveying. If the Object therefore is on a Hill, or Eminence, that is near, and of confiderable Height, it will be greater than is required in furveying, as the Hypothenufe of a right-angled Triangle is greater than the Bafe. To find the level Diftance, or Diftance of a Point within the Bafe of the Hill, right below the Object on the Top of it; pitch on fome remarkable thing that lies below, and in a Line with the Object, and take the Angle with that inftead of the Object on the Hill.

PROB.

P R O B. V.

Having the Diſtances of three Points A, B *and* C, *that form a Triangle, at any Station* S, *in the Direction of one of the Sides, to find its Diſtance from theſe Points.*

F I G. VII.

B Y P R O T R A C T I O N.

Take the Angle A S B with an Inſtrument; ſubtract that Angle from C A B, and the Remainder will be the Angle A B S; for C A B is the external Angle of the Triangle A B S, and therefore (by Eucl. B. I. Prop. 32.) is equal to A S B and A B S taken together. Then, at B, on the Side B A, draw the Angle A B S; produce C A, and it will interſect B S in S, the Point of Station; and S A, S C, S B will be the Diſtances required.

B Y C A L C U L A T I O N.

In the Triangle A B S, the Angle at S is found by Obſervation; the Angle B A S is the Supplement of C A B to 180°, and therefore the Angle A B S is alſo known: that is, in the Triangle A B S, all the Angles and a Side are known; from thence the other two Sides S A and S B are found by Trig. Sol. 1.

P R O B. VI.

Having the Diſtances of three Points A, B *and* C, *forming a Triangle; at any Station* S, *within the Triangle, to find its Diſtance from theſe Points.*

F I G VIII.

B Y P R O T R A C T I O N.

Make any one of the Sides, ſuppoſe A B, the Baſe: take with an Inſtrument the Angles A S C and C S B, which the two other Sides ſubtend: at

3.   B make

B make the Angle A B D (lying without the Bafe of the Triangle) equal to the Supplement of A S C to 180°; and the Angle B A D equal to the Supplement of C S B: thefe Sides produced, will interfect in D. Draw a Circle paffing through the three Points A, D and B; join C D, and it will interfect the Circle in S, the Point of Station; and S A, S C, S B will be the Diftances required.

Demonftration. The Angles A S D and A B D are equal, for they ftand in the fame Segment A S B D (Eucl. B. III. Prop. 21.) therefore A S C, the Supplement of A S D, is alfo the Supplement of A B D; and, by Con-ftruction equal to the firft obferved Angle. Again, B S D and B A D are equal, for they ftand in the fame Segment B S A D; and B S C, the Supplement of B S D, is alfo the Supplement of B A D; and therefore, by Conftruction, equal to the other obferved Angle; and S the Point of Station; and S A, S B, S C, the Diftances required.

BY CALCULATION.

1. In the Triangle A B D, the Angles B A D and A B D are known, being refpectively Supplements of the obferved Angles A S C and B S C; and therefore their Supplement A D B is known; and the Side A B oppo-fite to one of them: from thence (by Trig. Sol. 1.) find the Side A D. Then,

2. In the Triangle C A D, the Sides A C and A D are known, and the in-cluded Angle C A D (equal to C A B and B A D together) from thence find the Angle A C D, by Trig. Sol. 3.

3. In the Triangle A C S, the Angles at C and S are known, and the Side A C, oppofite to one of them; from thence (by Trig. Sol. 1.) find A S and C S.

PLATE I. FIG. IX.

If the Point of Station is in any of the Sides, as at S in the Side A B; take the Angle which one of the other Sides, fuppofe A C, fubtends there; and on any Part of A B, as D, make the Angle A D E equal to the ob-ferved Angle A S C: through C, draw the Line C S parallel to D E

cutting

cutting A B in S, and S will be the Point of Station. For C S and D E being parallel, the Angles A S C and A D E are equal (Eucl. B. I. Prop. 29.) A S C is therefore the obferved Angle, and S the Point of Station.

On account of the great Utility of thefe laft Problems in Surveying, I fhall fhew a general, and more ready Method, of finding, by Protraction, the Point of Station S, in the three principal Cafes foregoing ; communicated by Capt. *John Campbel* of his Majefty's Navy.

1. *When the obferved Angle* A S B *is lefs than* 90 *Degrees.*   From the Points A and B draw the Angles B A m and A B M, lying towards S, each equal to the Complement of the obferved Angle A S B, and the Interfection of the Lines A m, B M, will be the Center m of the Circle A S B.   From the Extremities of either of the other Sides of the Triangle A B C, as B C, draw the Angles B C n and C B N, each equal to the Complement of the obferved Angle C S B, and the Lines C n, B N, will interfect each other in n, the Center of the Circle C S B ; and the Point of Interfection of thefe two Circles fhall be the required Station S.   For,

The Angle A S B being lefs than a Right-Angle, the Line A B will divide the Circle A M S B into two unequal Segments, in the greateft of which (A M S B) S muft ftand (Eucl. B. III. Prop. 31.) and therefore the Center, m, which is always in the greateft Segment, will be on the fame Side of A B that S is. Alfo, in the Triangle m A B, the Angles A B m and B A M together, are the Supplement of the Angle A m B to two Right-Angles ; but A B m and B A m are (by Conftruction) the Supplement of twice A S B to two Right-Angles ; A m B is therefore double the Angle A S B ; and ftanding on the fame Arc (by Eucl. B. III. Prop. 30.) S muft be in the Circumference of the Circle A S B.

In the fame Manner it may be fhewn that S is in the Circumference of the Circle C S B, and therefore it muft be in their Interfection.

2. *When the obferved Angle* A S B (Fig. 19.) *is more than* 90 *Degrees:* Then fubtract 90 from it, and make the Angles at A and B each equal to the Remainder ; and to lie on the Side of A B, which is fartheft from S ;

and

and m, the Point of Interfection of thefe two Lines will be the Center of a Circle, which will pafs through A, B and S. For, the Angle A S B being more than 90 Degrees, the Line A B will divide the Circle into two unequal Segments, in the leaft of which (A S B) the Point of Station S muft be; and the Center m, therefore, on the Side of A B oppofite to S. Alfo, the Angle m A B = m B A = (by Conftruction) to the difference between A S B and a Right-Angle: alfo the Angle n C B = n B C = $\overline{C S B - 90^\circ}$.

The Point of Station S found inftrumentally.

The Point S may be readily laid down on a Draught, by drawing on a loofe tranfparent Paper indefinite Right-lines S A, S B, S C, at Angles equal to thofe obferved; which being placed on the Draught fo as each Line may pafs over, or coincide with, its refpective Object, the angular Point S will then coincide with the Place of Obfervation. Or,

Provide a graduated Semicircle of Brafs, about 6 Inches in Diameter, having three Radij with chamfered Edges, each about 20 Inches long, (or as long as it may be judged the Diftance of the Stations from the three given Objects may require) one of which Radij to be a Continuation of the Diameter that paffes through the Beginning of the Degrees on the Semi-circle, but immoveably fixed to it, the other two moveable round the Center, fo as to be fet and fcrewed faft to the Semicircle at any Angle. In the Center let there be a fmall Socket, or Hole, to admit a Pin for marking the central Point on the Draught. When the floped Edges of the two moveable Radij are fet and fcrewed faft to the Semicircle, at the refpective Degrees and Minutes of the two obferved Angles, and the whole Inftrument moved on the Draught until the Edges of the three Radij are made to lie along the three ftafimetric Points, each touching its refpective Point, the Center of the Semicircle will then be in the Point of Station S; which may be marked on the Draught, through the Socket, with a Pin. Such an Inftrument as this may be called a *Station-pointer*; and would be found convenient for finding the Point of Station readily and accurately, except when the given Objects were near; when the Breadth of the Arch, of the Radij, and of the Brafs about the Center of the Semicircle might hinder the Points to be feen, or the Radij to be placed fo as to comprehend a very fmall Angle between them.

<div style="text-align: right">P R O B.</div>

P R O B. VII.

Having the Diſtance and Poſition of two Points A and B; at two Stations, S and s, to find the Diſtance of theſe Stations from each other, and from the given Points.

P L A T E I. F I G. X.

1. At S, take the Angles A S s and B S s; and at s, take the Angles A s S and B s S.   Then,

2. Making S s any length, ſuppoſe 10, take it from a Scale of equal parts, and draw it on Paper: and at S and s, protract the reſpective obſerved Angles, and the Points A and B will be determined in Proportion to the aſſumed Length of S s.   Then, taking the protracted Length of A B from the Scale, ſay,

As the protracted Length of A B,
Is to the aſſumed Length of S s,
So is the true Length of A B,
To the true Diſtance of S and s.

3. The Diſtance S s being thus found, and the Angles at S and s obſerved, the Diſtances S A, S B and s A, s B, may be taken from the proper Scale, after a new Protraction; or calculated, as in Prob. I.

P R O B. VIII.

Having the Diſtance and magnetic Bearing of two Points, A and B protracted; at any Station S, (not very oblique to A B) to find its Diſtance from theſe Points, by the Needle.

[P L A T E I. F I G. XI.

At S, with a good magnetic Needle, take the Bearings of A and B, in Degrees and Parts of a Degree: then, from theſe Points draw out their

E   reſpective

respective Bearings in the opposite Direction, towards S : that is, if A bears exactly North; draw a Line from the Point A exactly South; if it bears East 10, or 20 Degrees southward, draw the Line West 10, or 20 Degrees northward, and so for any other Bearing. Draw the opposite Bearing of B in the same manner; and S, the Interfection of these two Lines, will be the Point of Station; and S A, S B, the Distances required.

This is an easy and ready way of finding the Distance of any Station, from two Places whose Distance has been accurately determined before ; and will be found convenient very often in the Course of a Survey ; and sufficiently exact on most Occasions ; provided the Places, A and B, are not very remote from the Station, nor the Interfection of their Bearings too oblique. If the Needle is good, a Distance of 20 Miles is not to be reckoned too far, when the Angle subtended by the two Places is not less than 50 Degrees, nor more than 140.

CHAP. IV.

Of the Examination of Surveying Instruments.

THE Accuracy of geometrical Menfuration depends so much on the Accuracy of the Instruments made use of in it, that it is a very necessary Qualification in a Surveyor to be capable of examining and adjusting them. Some Instruments are made in such a Manner, without any Necessity, and as if it were on purpose, that it is very troublesome to find whether all their Parts are exact or not; and for that Reason Surveyors are too apt to take them on Trust, without Examination : but this often creates more Trouble in their Business, and occasions Errors which they can neither account for, nor correct. If Surveyors were more cautious, Instrument-makers would become more careful.

How to examine the Accuracy of a Theodolite.

PLATE I. FIG. XII.

1. On a Level about a Mile or two long, such as the Margin of a Lake, or the High-water Mark along a well-sheltered Sand, when the Sea has been

<div align="right">smooth</div>

fmooth a little before, fet three upright Pales * A, B, C, exactly in a Line; and about half a Mile , or a Mile from each other. If it can be done, let the Line run exactly on fome remarkable Part of a diftant Object.

2. Set the Theodolite horizontal, with its Center right over the Hole B, where the middle Pole ftood: fet the Index at o Degrees, and turn the Theodolite till, through the Telefcope, you fee the Pole A at the vertical Wire; then fcrew the Inftrument faft in that Pofition. Next turn the Index to 90, and remark fome diftant Object exactly at the vertical Wire of the Telefcope: if no fuch Object is to be feen, fet up a Pole D in that Direction half a Mile off, or as far as it can be feen.

3. Then fet the Index at o Deg. again, and turn the Inftrument till you fee the Pole C, through the Telefcope exactly at the vertical Wire: fcrew the Inftrument faft in that Pofition; turn the Index to 90; look through the Telefcope; and if the Object, or Pole, D, is exactly at the vertical Wire, then is the Index right centered, and the graduated Circle exactly divided into four Quadrants; for the Line D B, ftanding on the right Line A C, makes the Angles on each Side, A B D and C B D, equal. But, if the Object is not feen exactly at the vertical Wire, obferve how much it is over, or falls fhort of it, and half that Difference is the Error of the Divifion at 90 †.

4. To find if the Graduations of each Quadrant are right: Apply the Beginning of the Divifions of the vernier Scale, to the Beginning of each Degree of the Theodolite; and if the End of the Divifions of the Vernier reaches the refpective Degree precifely in each Application, then the Graduations of the Theodolite are right; otherwife one, or more, are wrong. If each Degree is fubdivided, thefe Subdivifions may be examined in the fame manner. This is a very eafy and nice way of examining the Graduations of any Inftrument that has a vernier Scale on it.

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* To place a Pole upright; ftand ftraight up with your Feet clofe together; put one End of the Pole between your Toes, and take the other up along your Breaft and Chin, and in that Pofture prefs it down with both Hands till it ftands firm.

† By a proper Application of the above Principles, the Graduation of Inftruments, large or fmall, may be rendered as accurate as the Materials made ufe of will admit, and the leaft Degree of Inaccuracy in them readily difcoverable; as could be eafily fhewn, were this a Place for it.

To

To find if the Wire of the Telescope is exactly vertical: hang up a Plumb-line at some Distance; set the Theodolite level; look through the Telescope to the Plumb-line when at rest, and if the upright Wire moves exactly along the Plumb-line when the Telescope is elevated or depressed, then is the Wire exactly vertical. If the Wire crosses the Plumb-line in any Part, turn it by the proper Screws, or Pins, till you get it exact.

Cautions in taking Angles with a Theodolite.

1. Spread the Legs that support it pretty wide, and thrust them firm in the Ground, especially on Sand, or soft Ground; that they may not yield, or sink unequally during the Observations.

2. Set it level; otherwise the Angles will not be precise.

3. Screw the Ball firm in the Socket, that in turning the Index, the Diameter of the Theodolite may not vary from the Object it was directed to; which, without Care in the Observer, or in the Structure of the Instrument, will happen frequently.

4 The Angles should be taken twice over, and read off by different Persons.

5. It would often prevent Mistakes in Angles, and contribute to Dispatch, if a Theodolite was provided with two Telescopes, one above its Plane, and the other below it; the lower one to move round only when the Circumference of the Theodolite was turned; by which Means it would be readily seen through this Telescope when the Diameter shifted from the Direction of the Object it was fixed at. Also if these Telescopes shewed Objects erect, and in their natural Position, instead of being reversed and inverted; and if the Telescopes magnified more than they commonly do. It would likewise be an Advantage if the Vernier was made to give every Minute of a Degree, in place of four or five, as in most Theodolites.

Of Hadley's Sextant.

This Instrument may be used with great Advantage in Maritim Surveys, on most Occasions; being more portable, more readily applied to the taking

of

of Angles, and generally more accurately and minutely divided than Theodolites are: an Obferver is lefs liable to Miftakes with it; and, which is a very material Advantage, he can take Angles with it at Sea, as well as on Land. There are two Inconveniences attending the Ufe of it; one is, that fmall, or obfcure Objects, efpecially if the Ground rifes beyond them, cannot be eafily perceived in the Glaffes: the other is, that no Angle above 120 Degrees can be taken by it at once, and that fometimes there are not proper intervening Objects for dividing a larger Angle into two *.

A Brafs Sextant of nine Inches Radius, though it does not admit of Back-obfervations, will be found as convenient a Size as any for a Surveyor. It fhould be provided with a fmall Telefcope, that can be taken off and put on at Pleafure, for obferving celeftial Bodies; and with a Tube for terreftrial Objects, which is better than a thin Plate of Brafs with Holes in it. There fhould likewife be a Screw at the End of the Index, to bring the two Objects exactly to one another, after they have been firft brought near by the Hand; and if a Staff with a Ball and Socket is fitted to it, and a Belt to fupport the whole, it will be found a great Eafe to the Obferver. The Telefcope and Tube fhould be fo contrived, as to be raifed occafionally as high as the Middle of the tranfparent Part of the Horizon-glafs, for obferving Objects that are bright enough to be feen by Reflection from it.

Each of the Glaffes belonging to the Sextant fhould have its two Surfaces perfect Planes, and parallel to one another; and the Index and Horizon-glaffes fhould ftand perpendicular to the Plane of the Inftrument. Thefe Particulars of the Glaffes ought to be carefully attended to, and adjufted by the Inftrument-maker, before he gives the Sextant out of his Hand: for though Defects in the Glaffes may be detected by proper Examination, yet the want of Parallelifm and Plainnefs cannot be corrected without new Glaffes; and, to adjuft the Inclination, is troublefome to young Practitioners. The firft thing however which a Beginner fhould learn is, the eafieft way of holding the Sextant for making Obfervations, and of bringing the reflected

* Any Angle may be taken by the Back-obfervation, by one experienced in this manner of obferving; but the Back-obfervation is too difficult and troublefome to be recommended in general to all Practitioners; and requires a Sextant or Octant of at leaft 16 Inches Radius, to have fufficient Room for the Back-vanes, which is an inconvenient Size for Land Surveys.

Image and Object near each other by moving the Index. Tho' this requires Practice more than Precept, the following Directions may be found serviceable at firft.

How to hold the Sextant for taking Angles.

Whether the Sextant is to be held vertically, or horizontally with its Face uppermoft, it fhould be fupported chiefly with the Right-hand, and the Index governed by the Left, in the following Manner. For horizontal Angles; hold the Inftrument horizontally, with the Face uppermoft, and place the Thumb of the Right-hand againft the Edge of the curved Part on which the Sight-vane ftands, but fo as not to touch the Index when it is fet at o, or the Beginning of the Degrees; and extend your Fingers acrofs the Back of the Inftrument, fo as to lay hold of the oppofite Edge of the additional Part on which the Horizon-glafs ftands, placing the Fore-finger on one Side, the two next Fingers on the other Side of the greateft Swelling, and the Point of the little Finger againft the Back of the Inftrument. When there is no Staff and Belt, horizontal Angles are eafieft taken fitting with the right Ancle on the left Knee, and the right Elbow fupported by the right Knee. The Index may be managed by placing the Thumb of the left Hand againft the outer Edge of the graduated Arch, and keeping the End of the Index betwixt the two firft Fingers : or by taking the End of the Index between the Fore-finger and Thumb, and refting the other Fingers againft the middle Bar, or againft the Far-fide of the Inftrument, as a very little Practice will direct.

For taking vertical Angles : hold the Sextant in a vertical Pofition, with the Thumb and Fingers of the Right-hand, as before, for horizontal Angles; or as the Form of the Swelling at the Horizon-vane enables you to take the fureft Hold ; reft the Extremity of the Arch againft your Breaft, and that will enable you to manage the Index more eafily with your Left-hand.

When Angles are to be taken with the Inftrument inverted, or with the Face below, then it muft be held and fupported chiefly by the Left-hand, and the Right referved for governing the Index, in the following Manner. Hold the Sextant horizontal, with its Face downward : place the Thumb of your Left-hand on the Center-plate at the Back of the Index-glafs ; the

<div align="right">three</div>

three firſt Fingers above the Center-part, and the Inſide of the little Finger againſt the Edge of it; and when the Eye is applied to the Sight-vane, preſs the Edge of that Side againſt your Forehead : take care that the little Finger, by being too low, does not intercept the Sight of any of the Objects.

In all Obſervations, the Sextant ſhould be held in a Plane paſſing through the Eye of the Obſerver and the two Objects whoſe angular Diſtance is to be found.

How to examine the Glaſſes of a Sextant.

To find whether the two Surfaces of any one of the reflecting Glaſſes are parallel : apply your Eye at one End of it, and obſerve the Image of ſome diſtant Object reflected very obliquely from it ; if that Image appears ſingle and well defined about the Edges, it is a Proof that the Surfaces are parallel : on the contrary, if the Edge of the reflected Image appears miſted, as if it threw a Shadow from it, or ſeparated like two Edges, it is a Proof that the two Surfaces of the Glaſs are inclined to each other. If the Image in the Speculum, particularly the Sun, is viewed through a ſmall Teleſcope, the Examination will be more perfect.

To find whether the Surface of a reflecting Glaſs is a perfect Plane. Chuſe two diſtant Objects as nearly on a Level as can be had : hold the Sextant horizontal, with your Eye at the Sight-vane, view the Left-hand Object directly through the tranſparent Part of the Horizon-glaſs, and move the Index till the reflected Image of the other is ſeen below it in the ſilvered Part ; make the two Images unite juſt at the Line of Separation : then turn the Sextant round ſlowly in its own Plane, ſo as to make the united Images move along the Line of Separation of the Horizon-glaſs : if the Images continue united, without receding from each other, or varying their reſpective Poſition, the reflecting Surface is then ſufficiently plane.

To find if the reflecting Glaſſes are perpendicular to the Plane of the Sextant. Move the Index near the Middle of the Arch of the Sextant; apply your Eye obliquely near one End of the reflecting Glaſs, ſo as to ſee Part of the Arch of the Sextant by Reflection, and Part of it by direct Viſion : if the two Parts of the Arch form one uniform Curve, without

appearing

appearing in the leaſt above or below each other, then is the Glaſs perpendicular to the Plane of the Sextant. If the Image of the Arch ſeen by Reflection is higher than the Arch ſeen directly, then the Glaſs inclines forward; in which Caſe, ſlacken the fore-adjuſting Screw of the Glaſs, and ſcrew in the back one. If that Part of the Arch ſeen directly is higher than its Image ſeen by Reflection, then the Glaſs leans backward, and the back-adjuſting Screw muſt be ſlackened, and the fore one ſcrewed in. Be careful, in all Caſes where one Screw draws, or puſhes againſt another, to ſlacken one of them before you ſcrew up the other.

To find if the two Surfaces of a red or darkening Glaſs, are parallel and perfectly plane. This muſt be done by means of the Sun when it is near the Meridian, in the following Manner. Hold the Sextant vertically, and direct the Sight to ſome Object in the Horizon, or between you and the Sky, under the Sun; turn down the red Glaſs, and move the Index till the reflected Image of the Sun is in Contact with the Object ſeen directly: fix then the Index, and turn the red Glaſs round in its ſquare Frame; view the Sun's Image and Object immediately, and if the Sun's Image is neither raiſed nor depreſſed, but continues in Contact with the Object below, as before, then the Surfaces of the darkening Glaſs are true.

How to obſerve the horizontal Angle, or angular Diſtance, between two Objects.

Firſt adjuſt the Sextant, and if the Objects are not ſmall, pitch on a ſharp Top, or Corner, or ſome ſmall diſtinct Part in each to obſerve; then having ſet the Index to 0 Deg. hold the Sextant horizontally, as above directed, and as nearly in a Plane paſſing through the two Objects as you can; direct the Sight through the Tube to the Left-hand Object, till it is ſeen directly through the tranſparent Part of the Horizon-glaſs: keeping that Object ſtill in Sight there, move the Index till the other Object is ſeen by Reflection in the ſilvered Part of the Horizon-glaſs; then bring both Objects together by the Index, and by the Inclination of the Plane of the Sextant when neceſſary, till they unite as one, or appear to join in one vertical Line, in the Middle of the Line which divides the tranſparent and reflecting Parts of the Horizon-glaſs: the two Objects thus coinciding, or one appearing directly below the other, the Index then ſhews on the Limb the Angle which the two

Objects

Objects subtend at the naked Eye. This Angle is always double the Inclination of the Planes of the two reflecting Glasses to one another; and therefore every Degree and Minute the Index is *actually* moved from 0, to bring the two Objects together, the Angle subtended by them at the Eye will be twice that Number of Degrees and Minutes; and is accordingly numbered so on the Arch of the Sextant; which is really an Arc of 60 Degrees only, but graduated into 120°. As this has been demonstrated in several Books and Pamphlets, it is needless to insist on it here.

The Angle found in this Manner between two Objects that are *near* the Observer, is not precise; and may be reckoned exact only when the Objects are above half a Mile off. For, to get the Angle truly exact, the Objects should be viewed from the Center of the Index-glass, and not where the Sight-vane is placed; therefore, except the Objects are so remote that the Distance between the Index-glass and Sight-vane vanishes, or is as nothing compared to it, the Angle will not be quite exact. This Inaccuracy in the Angle between near Objects is called the *Paralax* of the Instrument; and is the Angle which the Distance between the Index-glass and Sight-vane subtends at any near Object. It is so small, that a Surveyor will seldom have Occasion to regard it: but if it shall happen that great Accuracy is required, let him chuse a distant Object exactly in a Line with each of the near ones, and take the Angles between *them* and that will be the true Angle between the near Objects. Or, observe the Angle between near Objects, when the Sextant has been first properly adjusted by a distant Object; then adjust it by the Left-hand Object, which will bring the Index on the Arch of Excess beyond 0 Degrees: add that Excess to the Angle found between the Objects, and the Sum will be the true Angle between them. If one of the Objects is near, and the other distant, and no remote Object to be found in a Line with the near one; adjust the Sextant to the near Object, and then take the Angle between them, and the Error of Paralax will be removed.

How to observe the Altitude of the Sun on the Sea, or on Shore at the Edge of the Sea.

Adjust the Sextant by the Horizon (as is afterwards directed:) raise the Telescope, or Tube, as high as the Middle of the transparent Part of the

F   Horizon-

Horizon-glafs; fet the Index to 0 Degrees; turn in the darkening-glaffes, or only one of them if the Sun is not very bright; turn your Face directly to the Sun; hold the Sextant in a vertical Pofition, with its Plane paffing as near through the Sun's Center and the neareft Part of the Horizon as you can, and direct the Sight to that Part of the Horizon; then move the Index from 0 on the Limb, till you fee the red Image of the Sun come down toward the Horizon. If there is any Difficulty in finding that red Image, it is either becaufe the Sun is obfcured by a Cloud, or becaufe the Sextant is not in a vertical Plane that paffes through the Sun, which muft be dif-covered by glancing at the Sun with your naked Eye, and in the latter Cafe, by turning your Body more directly to the Sun. Having brought the Sun's Image almoft down to the Horizon, then, with your Left-hand, fwing the Sextant backward and forward, from one Hand to the other, and the Image of the Sun will feem to defcribe the Arch of a Circle convex to the Hori-zon: move the Index till the lower Edge of the Image juft grazes on the Horizon; when it is at the loweft Point of the Arch apparently defcribed, then ftop the Index, and mark down the Degrees and Minutes fhewn on the Limb; which call The *obferved Altitude*. When this is corrected by the Sun's Semidiameter, the Dip of the Horizon, the Refraction, and the In-dex-error, if there is any, it will give the true Altitude of the Sun's Center.

How to take an horizontal Angle between two Objects with the Sextant inverted.

To obferve in this Manner: fet the Index at 0, and hold the Inftrument as above directed; direct the Sight to the Left-hand Object till it is feen through the tranfparent Part of the Horizon-glafs, and you will likewife perceive its reflected Image in the filvered Part: then advance the Index, and at the fame time keep the reflected Image in Sight, by turning your Body and the Sextant toward the Right-hand, till you fee the other Object through the tranfparent Part; make them join in the Middle of the Line of Separation of the Horizon-glafs, and the Index will fhew the Angle on the Limb.

This Method of obferving will be often convenient, becaufe, after a little Practice, an Angle may be taken more readily this way than with the Face
of

of the Sextant uppermoft ; and alfo becaufe the fainteft Object may often be found by direct vifion through the tranfparent Part of the Glafs, when it could not be fo eafily found by Reflection.

How to adjuft the Horizon-glafs for Obfervation, by a horizontal Line.

To adjuft the Horizon-glafs is, to make it parallel to the Index-glafs when the Pointer of the Vernier is placed at o, or the Beginning of the De- grees.   This is the moft important Adjuftment of all for an Obferver ; and fhould be done every Time one begins to make any Obfervations.   The ho- rizontal Lines fitteft for this Operation are, the Horizon of the Sea, which is the leaft ; and the Roof, or upper Part of the Wall of a large well-built Houfe above half a Mile diftant.

To adjuft by the Horizon of the Sea, or any other horizontal Line : turn the Index, till the Pointer of the Vernier ftands exactly at o on the Limb, and fix the Index there : hold the Sextant in a vertical Pofition, and obferve whether the Edge of the Sea-horizon (or other horizontal Line) feen in the filvered Part of the Glafs, makes one continued Line with the Edge of the Sea feen in the tranfparent Part : if it does not, and the Line appears broken, or one Part of it above the other, bring them into one ftraight Line by turn- ing the adjufting Lever at the Back of the Horizon-glafs ; then fix the Le- ver by the Button-fcrew in the Middle of it, and the Horizon-glafs is ad- jufted, or parallel to the Index-glafs.

To find the Error of this Adjuftment : move the Index a little from its Place ; hold the Sextant in a vertical Pofition as before, and turn the Index till the Line of the Sea-horizon (or other horizontal Line) feen in the filvered Part of the Horizon-glafs joins exactly in one ftraight Line with the Edge of the Sea feen through the tranfparent Part : then the Number of Minutes by which o on the Vernier differs from o on the Limb is the Error of the Ad- juftment ; and muft be allowed for in all the Angles taken with this Ad- juftment, in the following Manner. If the Pointer, or o on the Vernier, ftands on the quadrantal Arch, or to the Left-hand of o on the Limb, then this Error is to be fubtracted from the Angle fhewn on the Limb by the

F 2   Index ;

Index; but if o on the Vernier ſtands on the Arch of Exceſs, or to the Right of o on the Limb, then the Error of the Adjuſtment is to be added to the Angle ſhewn on the Limb.

To verify the Error of Adjuſtment found by this, or any other Method: ſet the Index ſo as to ſhew the exact Error found, and to ſhew it on the quadrantal Arch, if that Error is to be ſubtracted, but on the Arch of Exceſs, if the Error is to be added. Then fix the Index, and directing the Sight to ſome diſtant Object, take notice whether the direct and reflected Images perfectly coincide or not: if they do, the Index Error is truly determined; if not, it muſt be corrected by the Method proper for it.

When the Index is moved from you, to bring an Image and Object together, it will give a different Angle from that ſame Angle taken by moving the Index towards you. This, probably, is occaſioned by the Index bending or ſtarting a little by the Preſſure of the Hand. To correct this, when great Accuracy is required, take the Angles two or three times over each Way, and the Medium of all will be the true Angle.

How to adjuſt the Horizon-glaſs by a ſtraight vertical Line.

The Lines fitteſt for this are, the upright Corner of a Houſe, or a Pole ſet upright in the Ground, at leaſt half a Mile off.

Bring the Pointer of the Vernier to o on the Limb; hold the Plane of the Sextant horizontal; view the vertical Line in the Middle of the tranſparent Part of the Horizon-glaſs, and its Image in the reflecting Part, and turn the Lever till both make one continued Line, neither appearing to the Left, or Right of the other; then ſcrew the Horizon-lever faſt, and the Horizon-glaſs is adjuſted.

To find the Error of this Adjuſtment: move the Index out of its Place; then ſet the Vernier again to o on the Limb; hold the Plane of the Sextant horizontal; view the vertical Line directly through the tranſparent Part of the Horizon-glaſs, and its Image in the reflecting Part: if they make one continued Line, there is no Error; if they do not make one continued Line,

move

move the Index a little to one Side or the other till they do fo, and the Number of Minutes by which the Pointer of the Vernier differs from o on the Limb, is the Error of this Adjuftment; which is to be fubtracted from each Angle taken, if the Pointer ftands on the quadrantal Arch, and added when it is on the Arch of Excefs. In reading off the Minutes on the Arch of Excefs, remember to take their Compliment to 30, in Place of what the Vernier fhews.

To adjuft the Horizon-glafs by the Sun.

Set the Pointer of the Vernier to o on the Limb; hold the Sextant horizontal; raife the Telefcope, or Tube, as high as the Middle of the tranfparent Part of the Horizon-glafs; ufe a fmoked, or red Glafs to defend the Eye, and flip a Screen of Paftboard nine Inches fquare, with a Hole in the Middle, over the End of the Telefcope, to keep the Face from being fcorched; then view the Sun and its Image both through the tranfparent Part of the Horizon-glafs, and by the Lever make them cover each other exactly, fo as to appear as one Object; fcrew the Lever faft, and the Horizon-glafs is adjufted.

The Adjuftment may be made in the fame Manner by the Moon, or a Star, without a Darkening-glafs or Screen.

To find the Error of this Adjuftment; move the Index a little from its former Place at o; then, by the Index, make the two Images cover one another exactly as before; and the Number of Minutes by which the Pointer of the Vernier differs from o on the Limb, is the Error of Adjuftment, and muft be allowed for as above.

Another, and rather a nicer, Manner of adjufting by the Sun.

Set the Pointer of the Vernier to o on the Limb; hold the Quadrant horizontally, with the darkening Glafs and Screen to defend your Eye and Face; meafure the Diameter of the Sun, firft on the quadrantal Arch, and next on the Arch of Excefs; or with the Index, firft on the Left-hand of o

on

on the Limb, and then on the Right of it. If thefe two Diameters are equal, then is the Horizon-glafs adjufted: if the Diameters are unequal, turn the Horizon-lever a little one way or the other, till upon meafuring them again they are found equal : or, which is equivalent, and often more convenient, when the Error is fmall ; mark the Difference between the two Diameters, and make Allowance of half that Difference in each Angle ob-ferved on the Limb, adding or fubtracting it as before directed. In reading off the odd Minutes on the Arch of Excefs, remember to take the Compli-ment to 30 of what the Vernier fhews.

The Diameter of the Sun is meafured thus. Set the Pointer of the Vernier at 0 ; hold the Sextant horizontally ; by the Index bring the re-flected Image in external Contact with the direct Image ; note the De-grees and Minutes of the Pointer from 0 ; then bring them in Contact on the oppofite Side of the direct Image, and note the Degree and Minutes ; fee whether the Diameter on the quadrantal Arch, or the Diameter on the Arch of Excefs, is greateft ; mark the Difference, and referve the half of it for Ufe, if you do not correct the Error by the Lever.

The Adjuftment may be made pretty exact by taking two Diameters of a ftraight-fided Land-object in the fame Manner.

How to adjuft the Sextant by any remarkable Land-object at a Diftance.

It will often happen on a Survey, that no ftraight Line, either vertical or horizontal, nor no celeftial Body, can be feen to adjuft by. In this Cafe, pitch on fome fmall remarkable Object at a Diftance, as the tapering Top of a Hill, or Rock, or a fmall Hummoc, or Chimney-head, or detached Branch of a Tree, for this Purpofe. To adjuft by fuch an Object, fet the Index to 0 ; hold the Sextant horizontal ; view the Object through the tranf-parent Part, and its Image in the reflecting Part, of the Horizon-glafs ; and by the Lever, bring the Image directly below the Object in the Middle of the Line of Separation, fo as neither appears to one Hand of the other, but that if a vertical Line is imagined to be drawn through any Point of the Image, it would pafs through that fame Point of the Object ; then fcrew

the

the Lever faft, and the Horizon-glafs is adjufted.   This Method of adjuft-
ing may be fufficient for common Purpofes, but is not fo very exact as the
other Methods.

How to examine the Angle of the Sextant...

The Angle of the Sextant, meafured by the Arc of the Limb compre-
hended between o and 120 may be verified, firft, by adjufting the Glaffes
as before directed, and then taking, at one Station, five or fix horizontal
Angles, comprehending a whole Circle round ; add thefe Angles together,
and if their Sum amounts to 360 Degrees exactly, the Angle of the Sextant
and its Graduations may be concluded to be exact.   The Objects that form
thefe Angles muft be very remarkable and fharp, and all of the fame appa-
rent Height, to prevent Miftakes in taking them ; otherwife Inaccuracy in
the Obferver may be imputed to the Inftrument.

Another way of examining the Angle of the Sextant is, by fetting perpen-
dicular in a level Ground three Poles, or Staves, between four and five Feet
high, with Flags flying at each, fo as to form a Triangle, whofe greateft
Angle is lefs than 120 Degrees ; let the Diftance of the Poles from one an-
other be half a Mile, or as much farther as they can be feen diftinctly.   Af-
ter adjufting the Sextant, take the three Angles of the Triangle very exactly,
keeping the Center of the Sextant exactly on the Center of the Staff you ob-
ferve at ; and if the Sum of the Angles amounts precifely to 180 Degrees, the
Sextant may be con cluded to be good.   The feveral Graduations, and their Sub-
divifions, may be examined by the Vernier, as directed for the Theodolite.

How to examine the Accuracy of the two quadrantal Radij of an aftronomical Quadrant.

P L A T E I.   F I G. XIII.

1. On a level Line fet two Poles, A and B, perpendicular in the Ground,
about a Mile, or more, from one another ; let a Flag fly at the Top of
each, to render them more confpicuous ; and let the Poles appear on fome re-
markable fharp Part (C) of a remote Object ; the farther the Object is, the
better.   3

2. Put

2. Put the Quadrant on its Stand at B, with its Plane set horizontal, either by a spirit Level laid on it, or by a Carpenter's Level, and its Center right above the Hole where the Pole stood, and in the Position as at b. If the Stand cannot support it horizontally, lay the Quadrant steady on a firm Table. Then, with the Index at 0 Deg. look through the Telescope, and turn the Quadrant till you see the Object C exactly at the Intersection of the Wires. Let the Quadrant be kept firm in that Position, and turn the Index to 90, and observe through the Telescope what Object the Intersection of the Wires bears on : if it bears on nothing remarkable, set up a Pole and Flag D, in that Direction, as far off as can be seen.

3. With the Index at 90, turn the Quadrant on its Center a Quarter round, till it is in the Position a, so that you see the Pole A through the Telescope at the Intersection of the Wires. Then keeping the Quadrant firm in that Position, turn the Index to 0 Deg. and if through the Telescope you see the Object D, exactly at the Intersection of the Wires, then the two Radij of the Quadrant, drawn through 0 and 90, are precisely at right Angles, and the Axis of the Telescope parallel to the Radius it is fastened to. If the Object D, does not appear exactly at the Intersection of the Wires, but on one Side of it ; then half its Distance from the Intersection is the Error of the Quadrant ; and is either in the Angle of the two Radij, or in the Axis of the Telescope, which is a Line supposed drawn through the Center of the Eye-glass and the Intersection of the Cross-wires. It is much more likely to be in the Telescope than in the quadrantal Radij ; and therefore to correct it, the Wires in the Telescope must be shifted by their proper Screws, half the Distance between the Object and Intersection of the Wires ; and the Quadrant examined over again as before. If it is not right on this second Examination, correct the Wire over again by the Screws, and examin the Quadrant a third Time ; and if the Object D, and the Intersection of the Wires still disagree, conclude the Error to be in the Angle of the Radij between 0 and 90. Mark how much that Error is, and by it correct all future Observations. This Method is liable to a little Inaccuracy, if the Plane of the Quadrant is not made exactly horizontal.

How

How to examine and adjuft an aftronomical Quadrant.

1. Set up the Quadrant on the Margin of a Lake, clofe to the Edge of the Water, fo that the Center of the Quadrant is juft over the Water : (or, in a well-fheltered Bay when the Sea is fmooth, right over the High-water Mark) fet one Side of the Quadrant perpendicular by the Plummet ; and meafure the Height of the Center of the Telefcope above the Surface of of the Water (or above the High-water Mark) in Inches and Parts of an Inch.

2. About half a Mile off (but not above a Mile) fet a Pole ftraight up in in the Edge of the Lake (or on the High-water Mark) with a confpicuous fliding Crofs-piece on it : let one Edge of the Crofs-piece be fet as high above the Surface of the Water (or High-water Mark) as the Center of the Telefcope was, and about 2 Inches higher, if the Diftance of the Stations is half a Mile ; $4\frac{1}{2}$ Inches higher if $\frac{3}{4}$ of a Mile, and 8 Inches higher if their Diftance is one Mile ; for the Height of the Tangent above the Surface of the Earth in thefe Arcs *.

3. Set the Index of the Quadrant to o Degrees, or exactly to the horizontal Radius, and direct the Telefcope to the Pole : if, while the vertical Wire runs along the Pole, the horizontal Wire runs exactly along that Edge of the Crofs-piece which was fet as high as the Center of the Telefcope, the Quadrant and Telefcope are right. If the horizontal Wire does not coincide

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* The Height of a Tangent to the Extremity of any fmall Arc above the other Extremity of that Arc, is a third Proportional to the Diameter of the Earth and the Length of the Arc. For, imagine a Diameter drawn to one End of the Arc, and produced till it meets a Tangent drawn to the other End ; then, by Eucl. B. III. Prop. 36. the Rectangle of the Diameter (in this Cafe the fame with the Secant) and produced Part is equal to the Square of the Tangent. If the Diameter is called d, the produced Part p, the Tangent t, and the Arc a ; the two equal Rectangles will be expreffed thus $d \times p = t \times t$: and becaufe a fmall Arc and its Tangent are fo nearly equal, that one may be affumed for the other ; in place of $t \times t$, fubftitute $a \times a$, and it will be $d \times p = a \times a$. When two Rectangles are equal, their Sides are reciprocally proportional (Eucl. B. VI. Prop. 14.) therefore $d : a : : a : p$; that is, as the Diameter is to any fmall Arc, fuppofe one Minute, fo is that Arc to the Height of the Tangent above it. By this Proportion the Numbers in the Text were found, fuppofing the Diameter of the Earth to be 41798147 Feet.

in

in that Manner, ſhift it by the proper Screws till it does ſo, and the qua-drantal Angle and Axis of the Teleſcope will then be right.

The Screws for ſhifting the Wires are on the Teleſcope, at the common Focus of the Object and Eye-glaſs. If you ſee the Edge of the Croſs-piece below the horizontal Wire, eaſe the upper Screw, and ſcrew in the lower one *; if the Edge of the Croſs-piece appears above the horizontal Wire, eaſe the lower Screw, and ſcrew in the upper one, till the horizontal Wire coincides with the Edge of the Croſs-piece; and the Axis of the Teleſcope is then right.

This Adjuſtment may be verified, by placing the Quadrant where the Pole ſtood, and the Pole where the Center of the Quadrant was, and the Axis of the Teleſcope, and the Edge of the Croſs-piece, at the ſame Height above the Surface of the Water as at firſt; then make the Radius of the Quadrant perpendicular by the Plummet, ſet the Index to o Degrees, look through the Teleſcope, and if the horizontal Wire and Edge of the Croſs-piece coincide again, the Angle of the Quadrant and Axis of the Teleſcope are certainly right. If any Difference is perceived, move the horizontal Wire, by its Screws, half that Difference, and it will be rectified.

The Graduations of a Quadrant may be examined in the ſame Manner as thoſe of the Theodolite above mentioned, by applying the Vernier to the ſe-veral Degrees, and Parts of a Degree.

How to adjuſt Bird's *twelve-inch Quadrant, as made before the Year* 1751.

For performing this, there are three principal Parts to be adjuſted, 1. The Pillar is to be ſet perpendicular to the Horizon. 2. One Side of the Qua-drant is to be ſet perpendicular. 3. The Axis of the Teleſcope, or Line of Sight, is to be made parallel to the horizontal Radius of the Quadrant.

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* As the Teleſcope inverts Objects, what appears below the horizontal Wire is really above it, and therefore, ſcrewing in the lower Screw, which puſhes up the Wire, will bring it nearer the Object. The contrary is true of the upper Screw.

1. To

1. *To set the Pillar perpendicular.*

1. Set the Brafs Pedeftal on a firm Support. An iron-bound Cafk, with a Free-ftone, or thick Slate, kept on purpofe to cover the Top of it, is as good and convenient for a Surveyor as any thing. Then hang the Quadrant on the Pillar, and by the Spirit-level and Screws in the Feet, the Pillar may be fet perpendicular in the following Manner. Turn the Quadrant till the upper Side is parallel to two oppofite Feet, and with one Hand unfcrew that Screw of the Foot toward which the Buble inclines, and, at the fame time, with the other Hand fcrew in the oppofite Screw, till the Buble refts equally between the two Marks, or Scratches, on the glafs Tube: then turn the Quadrant, horizontally, half round; and if the Buble does not reft exactly between the Scratches as before, by unfcrewing that Screw towards which the Buble inclines, and at the fame fcrewing in the other, make the Buble move over half the Space in the Tube by which they differ, and remember toward which End it inclines. Then turn the Quadrant one Quarter round, till its upper Side is parallel to the other two Feet; and if the Buble does not reft in the fame Place, with refpect to the Scratches, as it did before, make it do fo by the Screws in the Feet; and then bring it equally between the Scratches, by lowering that End of the Tube toward which the Buble ftood, or raifing the other End. For doing this, there are three Screws at each End of the Tube. To lower one End, flacken the right and left, or pufhing, Screws, and fcrew in the Middle Screw, till the Buble refts equally between the two Scratches: then the Pillar and Level are right, or nearly fo. To prove if they are exact, or to make them fo, if they are not; begin the fame Procefs over again, by firft turning the Quadrant half round, and if the Buble refts not equally between the Scratches, move it half the Difference by the Screws in the Feet; and then quarter round, and adjufting the Level firft fo far by the Screws in the Feet, and next by raifing or lowering one End of the Tube as before directed; till you get the Buble to ftand in the fame Part of the Glafs when the Quadrant is turned half round and quarter round; and the Pillar and Level will then be right.

Let it be adverted here, that in turning the Screws of the Feet, the Feet themfelves will be apt to fhift infenfibly on the Support; which, if not pre-

vented, will render this Part of the Adjuftment troublefome and tedious. To guard againft this, fmall Grooves, or Furrows, the Width of the Screw-ends fhould be funk a little in the Stone, or Support, and the Screws placed in thefe Grooves; or fome other equivalent Contrivance to keep the Feet from fhifting.

2. *To make one Side of the Quadrant perpendicular.*

This is done by making the Plumb-line hang firft over the fine Point at the Arrow-head, on the center Plate; and next to cover the other fine Point on the Arch below.

It is made to hang over the upper Point, by fcrewing the elaftic Bit of Brafs (over which the Wire of the Plummet goes) out, or in, by its upper Screw-nail. It is made to hang over the lower Point, by the adjufting Screw within the Quadrant, which is turned by a round brotched Brafs-button on its Head.

The Plummet fhould be made to hang in a fmall Cup, or Veffel, filled with Water, to make it more fteady, and reft fooner: and if the Veffel is faftened by an Arm to the Pillar of the Pedeftal, fo as to move round along with the Quadrant, it will be the more convenient.

The Plumb-line fhould be made to hang very near the Plane of the Quadrant, at the lower Arrow, but not to touch it: which is done by preffing with the Hand the elaftic Bit of Brafs before mentioned, a little backward or forward.

3. *To adjuft the Telefcope, or to make its Axis horizontal, when the Index is at* 90 *Degrees.*

Set the Index to 90, keeping the Plummet and Level right: then direct the Telefcope to fome diftant Object above a Mile off, (but the farther the better) till you fee a remarkable Part of it exactly at the horizontal Wire: then take off the Quadrant from the Pillar, by unfcrewing the two large Iron-fcrews; and invert the Quadrant, by fcrewing it on again with the

Arch

Arch uppermoſt : then ſcrew to the Arch of the Quadrant a crooked Bit of Braſs, with a Notch in it, as near the Arrow as you can, and hang the Plum- met over that Bit of Braſs, moving it to one Side or the other, till the Line covers the Point on the Arch ; and if it does not then cover the Point on the Center-plate alſo, make it do ſo by the Screws in the Feet : then look through the Teleſcope ; and if the horizontal Wire cuts the ſame Part of the Object it did before Inverſion, the Teleſcope is right. If the Object ap- pears higher or lower, the Wire in the Teleſcope muſt be moved half the Difference, by the two Steel-ſcrews near the Eye-end of the Teleſcope : if the Object appears higher than the horizontal Wire, eaſe the lower Screw, and ſcrew in the upper one ; if the Object appears below, eaſe the upper Screw, and ſcrew in the lower one ; till the horizontal Wire cuts the diſtant Object at half the Difference it did before inverting it : then it is adjuſted for Obſervation.

The Wire in the Teleſcope that is applied to the Limb of the Sun, in taking its Altitude, ought to be exactly horizontal when the Plane of the Quadrant is perpendicular. To find if it is ſo : adjuſt the Quadrant by the Level and Plummet, as before directed ; then point rhe Teleſcope to ſome ſmall diſtinct Object at a Diſtance, as the Top of a Rock, a Chimney-head, &c. and remark a particular Part of it which the Wire croſſes : turn the Quadrant a little about gently, towards one Side ; and if all Parts of the Wire paſs over the ſame Part of the Object, the Wire is truly horizontal. But if one End of the Wire croſſes the Object higher, or lower, than the other, preſs the two ſmall Screws that govern the Wire between your Fin- ger and Thumb, and at the ſame Time turn them ſide-wiſe, but in oppoſite Directions, till, upon looking again, and turning the Quadrant, you find all Parts of the Wire paſs over the ſame Part of the Object ; then it is truly horizontal.

Theſe Adjuſtments may ſeem difficult and tedious at firſt ; but they are neceſſary : and by practiſing two or three Times within Doors, till a right way of handling the ſeveral Parts of the Quadrant becomes familiar, they will be found much eaſier than may at firſt be imagined.

When

When a Quadrant of this Sort, made by a good Artift, has been firft veri-
fied and adjufted, the fimpleft and eafieft way of examining a Theodolite or
Hadley's Quadrant is, firft to take an Angle between any two fmart Objects
with the verified Quadrant, and then with the Inftrument under Examina-
tion; and if they differ, to afcribe it to the latter.

How to examine a magnetic Needle.

Firft fet the Box level; by raifing, or lowering, one Side of it, till each
End of the Needle, when it plays from Side to Side, runs along the Cir-
cumference of the graduated Circle in the Box; and both Ends of the
Needle, when at reft, point equally high on it. Then turn the Box gently,
till one End of the Needle refts at the Beginning of the Graduations exactly,
and if the other End points exactly to 180°, the oppofite Graduation, the
Needle is fo far right centered. Next turn the Box 90 Degrees round, and
if the Ends of the Needle then point precifely to the oppofite Degrees, then
the Needle is truly centered. Each Degree may be tried in the fame
Manner.

Obferve likewife if the Cap in the Center of the Needle is fmall and taper-
ing in the Infide, or large and fpherical: if it is a Portion of a large Sphere,
the Point of the Steeple will be apt to reft on different Parts of it, and by
that Means vary the Center of the Needle, and caufe it to point wrong.

C H A P.

C H A P. V.

Meridional Problems by the Stars; and Variation of the magnetic
Needle by the Sun.

*How to fix a meridian Line by a Star, when it can be seen at its greatest
Elongation on each Side of the Pole.*

PROVIDE two Plummets. Let one hang from a fixt Point: let the
other hang over a Rod, supported horizontally about 6 or 8 Feet above
the Ground, or Floor in a House, and so as to slide occasionally along the
Rod: let the moveable Plummet hang four or five Feet northward of the
fixt one. Some time before the Star is at its greatest Elongation, follow it, in
its Motion, with the moveable Plummet, so as a Person a little behind the fixt
Plummet may always see both in one, and just touching the Star. When the Star
becomes stationary, or moves not beyond the moveable Plummet, set up a
Light on a Staff, by Signals, about half a Mile off, precisely in the Di-
rection of both the Plummets. Near twelve Hours afterwards, when the
Star comes towards its greatest Elongation on the other Side of the Pole,
with your Eye a Foot or two behind the fixt Plummet, follow it with the
moveable Plummet, till you perceive it stationary as before: mark the Di-
rection of the Plummets then by a Light put up precisely in that Line:
take the Angle between the Places of the two Lights with *Hadley*'s Qua-
drant, or a good Theodolite, the Center of the Instrument at the fixt Plum-
met; and a Pole set up in Day-light, bisecting that Angle, will be exactly
in the Meridian seen from the fixt Plummet.

This Observation will be more accurate if the Eye is steadied by view-
ing the Plumb-lines and Star through a small Slit in a Plate of Brass stuck
upright on a Stool, or on the Top of a Chair-back.

This Problem depends on no former Observations whatever: and as there
is nothing in the Operation, or Instruments, to affect its Accuracy, but
what any one may easily guard against, it may be reckoned the surest Foun-
dation for all subsequent celestial Observations that require an exact Me-
ridian Line. The only Disadvantage is, that it cannot be performed but in
Winter, and when the Stars may be seen for 12 Hours together; which re-
quires the Night to be about 15 Hours long.	*How*

How to fix a Meridian-line by two circumpolar Stars that have the same Right-ascension ; or differ precisely 180 Degrees.

Pitch on two Stars that do not set, and whose Right-ascensions are the same, or exactly 180 Degrees different; take them in the same vertical Circle by a Plumb-line, and at the same Time let a Light be set up in that Direction, half a Mile, or a Mile off, and the Light and Plummet will be exactly in the Meridian.

In order to place a distant Light exactly in the Direction of the Plumb-line and Stars, proceed in the following Manner. Any Night before the Observation is to be made, when the two Stars appear to the Eye to be in a vertical Position, set up a Staff in the Place near which you would have the Plummet to hang ; and placing your Eye at that Staff, direct an Assistant to set another Staff upright in the Ground, 30 or 40 Yards off, as near in a Line with the Stars as you can. Next Day, set the two Staffs in the same Places ; and in their Direction, at the Distance of a Mile, or half a Mile northward, cut a small Hole in the Ground, for the Place where the Light is to stand at Night ; and mark the Hole so, that a Person sent there at Night may find it.

Then chuse a calm Night, if the Observation is to be made without Doors ; (if it is Moon-light, so much the better) and half an Hour before the Stars appear near the same Vertical, have a lighted Lanthorn ready tied to the Top of a Pole, and set upright in the distant Hole marked for it the Night before ; and the Light will then be very near the Meridian, seen from the Place marked for the Plummet. At the same Time, let another Pole, or Rod, 6 or 8 Feet long, be supported horizontally where the Plummet is to hang, six or seven Feet from the Ground, and hang the Plumb line over it, so as to slip easily along it either to one Hand or the other, as there may be Occasion (or tie a Staff firmly across the Top of a Pole six or seven Feet long ; fix the Pole in the Ground, and make the Plumb-line hang over the Cross-staff.) Let the Weight at the End of the Line be pretty heavy, and swing in a Tub of Water, so as it may not shake by a small Motion of the Air. Then shift the Plumb-line to one Hand, or the other, till one Side of

the

the Line, when at Reft, cuts the Star which is neareft the Pole of the World, and the Middle of the Light together : as that Star moves, continue moving the Plumb-line along the Rod, fo as to keep it always on the Light and Star, till the other Star comes to the fame Side of the Plumb-line alfo ; and then the Plummet and Light will be exactly in the Meridian.

There are not two remarkable Stars near the North Pole, with the fame Right-afcenfion precifely, or juft a Semicircle's difference : but there are three Stars that are very nearly fo, viz. the Pole-ftar, ε in Urfa Major, and γ in Cafiopeia.   If either of the two laft, particularly ε, are taken in the fame Vertical with the Pole-ftar, they will then be fo very near the Meridian, that no greater Exactnefs need be defired for any Purpofe in Surveying. At London γ is about 1′ Weft of the Meridian then ; and ε much nearer it, on the Weft Side likewife.   Stars towards the S. Pole proper for this Obfervation are, , , in the Head of the Crofs ; α, in the Foot of the Crofs ; and α, in the Head of the Phenix.

How to find a Meridian-line by a circumpolar Star, when it is at its greateft
Azimuth from the Pole.

By a circumpolar Star is here meant, a Star whofe Diftance from the Pole is lefs than either the Latitude, or Co-latitude, of the Place of Obfervation.

1. Find the Latitude of the Place in which you are to obferve the Star.

2. Pitch on a Star whofe Declination is known, and calculate its greateft Azimuth from the North, or elevated Pole.

3. Find at what Time it will be on the Meridian the Afternoon you are to obferve ; fo as to judge about what Time to begin the Obfervation.

4. Prepare two Plummets, and follow the Star with one of them, (as directed in Page 47.) until the Star is ftationary, then fet up a Light half a Mile, or a Mile off, in the Direction of the Plumb-line and Star, and mark the Place of the Light in the Ground, and alfo of the Plumb-line.

5. Next day fet up a Pole where the Light ftood, with a Flag flying at it. Then with a Theodolite, or *Hadley*'s Quadrant, fet the Index to the Degree

H   and

and Minute of the Star's Azimuth from the North, found before; direct, by waving to one Hand or the other, an Aſſiſtant to ſet up a Staff on the ſame Side of the Pole with a Flag as the Pole of the World was from it, ſo as at the Plumb-line theſe two Lines may make an Angle equal to the Azimuth of the Star, and the Plumb-line and Staff will then be in the Meridian.

When any Star is deſcending, it is on the Weſt-ſide of the Pole of the World; while it aſcends, it is on the Eaſt ſide of it.

The Pole of the World is always between the Pole-ſtar and Urſa-major: ſo that when Urſa-major is W. or E. of the Pole-ſtar, the Pole of the World is W. or E. of it likewiſe.

To find the greateſt Azimuth of a circumpolar ſtar from the Meridian, uſe the following Proportion.

Coſine of the Lat. : R :: S. of the Star's Diſtance from the Pole : S. of its greateſt Azimuth.

The greateſt Azimuth is when the Star is ~~below~~ above the horizontal Diameter of its diurnal Circle ~~as many Degrees, (meaſured on that Circle) as is equal to the Star's polar Diſtance.~~

On the N. Side of the Equator, the Pole-ſtar is the moſt convenient for this Obſervation; for the Time when it is at its greateſt Elongation from the Pole, may be known ſufficiently near by the Eye; by obſerving when ε in Urſa-major and γ in Caſiopeia appear to be in a horizontal Line, or parallel to the Horizon; for that is nearly the Time. Or, the Time may be found more preciſely by making faſt a ſmall Piece of Wood along the Plumb-line when extended, with a Croſs-piece at right Angles to the Top of the upright Piece, like the Letter T; when the Plummet is at Reſt, and both Stars are ſeen touching the upper Edge of the Croſs-piece, then they are both horizontal. It is another Conveniency in making uſe of this Star, that it changes its Azimuth much ſlower than other Stars, and therefore affords more Time to take its Direction exact.

On the South-ſide of the Equator, the Head of the Croſs is the moſt convenient for this Obſervation, being neareſt to the S. Pole; and the Time of

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its coming to the horizontal Diameter of the diurnal Circle, when it appears in a horizontal Line with the Foot of the Crofs, or the Head of the Phenix; and its greateft Azimuth, *at the Equator* one Hour fixteen Minutes before or after that, as it is E. or W. of the Meridian. The Pole of the World is between the Head of the Crofs and the laft of thefe Stars.

To find when any Star will come to the Meridian, either in the South or North. Find the Star's right Afcenfion, in Time, from the moft correct Tables, alfo the Sun's right Afcenfion for the Day and Place propofed; their Difference will fhew the Difference between their Times of coming on the Meridian in the South, or between the Pole and Zenith; which will be after Noon if the Sun's right Afcenfion is leaft, but before Noon if greateft. Eleven Hours 58 Minutes after the Star has been on the Meridian above the Pole, it will come to the Meridian North of it, or below the Pole.

Given the Latitude of the Place, and the Declinations and right Afcenfions of two Stars in the fame vertical Line; to find the horizontal Diftance of that Vertical from the Meridian; the Time one of the Stars will take to come from the Vertical to the Meridian; and the precife Time of the Obfervation.

CASE I.

When the two Stars are northward of the Zenith.

PLATE I. FIG. XV.

Let Z P O be a Meridian, Z the Place of Obfervation, H O its Horizon, and Z V a vertical Circle paffing through two known Stars, s and S; P the Pole, E Q the Equator, P s D and P S d Circles of Declination (or right Afcenfion) paffing through thefe Stars: then is Z P the co. latitude of the Place, P s and P S the co. declination of the two Stars refpectively, and the Angle s P S the neareft Diftance of their Circles of right Afcenfion; V O the Arc of the Horizon between the vertical Circle and the Meridian; and d Q the Arc of the Equator between the Star S and the Meridian. When, in the Triangle P Z s, the Angles P Z s and s P Z (meafured by the Arcs V O and D E) are found, the Problem is folved.

H 2   SOLUTION.

SOLUTION.

1. Begin with the oblique-angled Triangle P s S; in which are given two Sides P s and P S, the co. declinations of the two Stars respectively, and the included Angle S P s; which Angle is the Difference of their right Ascensions when it is less than 180 Degrees; but if their Difference is more than 180°, then the Angle S P s is equal to the lesser Right-ascension added to what the greater wants of 360 Degrees. From hence find the Angle S s P by the following Proportions.

As Radius
Is to the co. sine of the given Angle (S P s)
So is the Tan. of the Side opposite the required Ang. (P s)
To the Tan. of an Angle, which call M.

M. is like the Side opposite the Angle sought, if the given Angle is acute; but unlike that Side, if the given Angle is obtuse *.

Take the Difference between the Side (P S) adjacent the required Angle and M; call it N. Then,

Sine N : Sine M. : : Tan. of the given Angle (S P s) : Tan. of the required Angle (S s P) which is like the given Angle if M is less than the Side (P S) adjacent to the required Angle; but unlike the given Angle if M is greater than P S.

2. Next in the oblique-angled Triangle P s Z there are given two Sides, P Z the co-latitude of the Place of Observation; P s, the co. declination of the Star s; and the Angle P s Z opposite to one of them, which is the Supplement of P s S (last found) to 180° : from thence find the Angle P Z s opposite the other Side, by the following Proportion.

. *Sine of* P Z : *Sine* P s Z : : *Sine* P s : *Sine* P Z s. *either acute or obtuse.*

This Angle P Z s, measured by the Arc of the Horizon V O, is therefore equal to the horizontal Distance of the Vertical of the two Stars from the

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* Two Arcs, or Angles, are said to be like, or of the same Kind, when both are less than 90°, or both more than 90° : but are said to be unlike, when one is greater and the other less than 90° : and are made like, or unlike, to another, by taking the Supplement to 180° of the Arc, or Angle, produced in the Proportion, in place of what the Proportion brings out.

Meridian.

Meridian.   Let the Direction of the Vertical be taken by a Plumb-line and diſtant Light, as before directed, or by two Plumb-lines, and marked on the Ground.   Next Day, the Degrees and Minutes in the Arc V O may be added to it by *Hadley*'s Quadrant, and a Pole ſet up there, which will be in the Direction of the Meridian from the Pumb-line.

3. Laſt, in the ſame Triangle P s Z, find the Angle s P Z between the given Sides, by the following Proportions.

> *As Radius*
> *Is to the Tan. of the given Angle* (P s Z)
> *So is the co. s. of the adjacent Side* (P s)
> *To the co. t. of* M.

M is acute, if the given Angle and its adjacent Side are like ; but obtuſe, if the given Angle and the adjacent Side are unlike.

> *As the co. t. of the Side adjacent to the given Angle* (P s)
> *Is to the co. t. of the other Side* (P Z)
> *So is the co. s.* M
> *To the co. s. of an Angle, which call* N.

N is like the Side oppoſite the given Angle, if that Angle is acute ; but unlike the Side oppoſite the given Angle, if that Angle is obtuſe.

Then the required Angle s P Z is either equal to the Sum or Difference of M and N, as the given Sides are like or unlike.

The Angle s P Z, thus found, added to s P S, and their Sum ſubtracted from 180° will leave the Angle d P Q, or the Arc d Q that meaſures it, which is the Arc of the Equator the Star S muſt paſs over in coming from the Vertical, Z V, to the Meridian.   Which converted into Time, and meaſured by a Clock, or Watch, beginning to reckon the preciſe Moment that a Plumb-line cuts both Stars, will ſhew the Hour, Minute, and Second that S is on the Meridian.

Find, by the right Aſcenſion of the Star and Sun, at what Time that Star ſhould come to the Meridian in the North the Night of the Obſervation ; ſubtract from it the Time the Star takes from the Vertical to the Meridian, and the Remainder, corrected by the Sun's Equation, will be the Time when the two Stars were in the ſame Vertical.

The

The loweſt of the two Stars comes ſooneſt to the Meridian below the Pole; the higheſt of them comes ſooneſt to that Part of the Meridian which is above the Pole.

The nearer in Time one of the Stars is to the Meridian when the Obſervation is made, it is the better: for then an ordinary Watch will ſerve to meaſure the Time ſufficiently exact. It is ſtill more advantageous if one of them is above the Pole when the other is below it.

The nearer one of the Stars is to the Pole, and the farther the other is from it, the more exact will this Obſervation be; becauſe the Change of the Vertical will be the ſooner perceived. For this Reaſon, in North Latitudes, Stars northward of the Zenith are preferable to thoſe that are ſouthward of it.

If the two Stars are paſt the Meridian when they are obſerved in the ſame Vertical, then the Arc d Q gives the Time S took to come from the Meridian to the Vertical; and muſt be added to the Time when that Star was on the Meridian to give the Time of the Obſervation: and the Arc of the Horizon V O muſt be marked on the Ground on the Side of the Vertical contrary to what it would have been in the foregoing Suppoſition; that is, eaſtward *below* the Pole, and weſtward *above* it.

When two Stars come to the vertical Line near the Meridian, it may be difficult to judge on which Side of it they are at that Time; for determining this, the following Rules may ſerve.

The right Aſcenſion of two Stars may be either each *leſs*, or each *more* than 180 Degrees, or *one more* and the *other leſs*.

When the right Aſcenſion of each of the Stars is *either leſs, or more*, than 180 Degrees, they will come to the ſame Vertical on the *Eaſt-ſide* of the Meridian when the Star with the *greateſt* right Aſcenſion is the *loweſt*; but on the *Weſt* Side of the Meridian when it is *higheſt*.

When

When the right Afcenfion of one of the Stars is more than 180 Degrees, and that of the other lefs.

If the right afcenfion of the higheft is lefs than 180°, but greater than the Excefs of the other's right Afcenfion above 180°, then they come to the Vertical on the *Eaft Side* of the Meridian. But if the right Afcenfion of the higher Star is lefs than that Excefs, they come to the Vertical on the *Weft Side* of the Meridian.

If the right Afcenfion of the higher Star is *more* than 180 Degrees, and that Excefs is *lefs* than the right Afcenfion of the lower Star, then they come to the Vertical on the *Weft Side* of the Meridian ; but if the Excefs of the higher Star's right Afcenfion above 180° is *more* than the right Afcenfion of the lower Star, then they come to the fame Vertical on the *Eaft Side* of the Meridian.

C A S E   II.

When the two Stars are in the fame Vertical foutbward of the Zenitb.

P L A T E I.   F I G. XVI.

When two Stars are obferved in the fame vertical Line *foutbward* of the Zenith (or toward the depreffed Pole) the Operations and Solutions are nearly the fame as in Cafe 1. For let P Z O be a Meridian, Z the Place of Obfervation, O H its Horizon, Z V a vertical Circle paffing through the two Stars S and s ; P the Pole, Q E the Equator, P D and P d two Circles of Declination (or right Afcenfion) paffing through the two Stars refpectively : then is Z P the co. latitude of the Place, P S and P s the co. declination of the two Stars refpectively, the Angle S P s the Difference of their right Afcenfions, the Angle S Z Q (or O V the Arc of the Horizon which meafures it) the Diftance of the Vertical from the Meridian ; the Angle s P Z (or d Q which meafures it) the Arc of the Equator, which s muft pafs over from the Vertical to the Meridian, which converted into Time, and meafured by a Watch, will fhew when s is on the Meridian ;

3

and

and fubtracted from the calculated Time that the Star fhould come to the Meridian, will (when corrected by the Sun's Equation) give the true Time of the Obfervation: S P s is the Triangle to begin the Solution with; and in the Triangle s P Z, the Angles s P Z and s Z P, when found, will give the Solution of the Problem, as in Cafe 1. For the Supplement of s Z P to 180° is the Angle V Z O (or its Meafure O V) the horizontal Diftance of the Vertical from the Meridian; the Angle s P Z (or its Meafure d Q) is the equatorial Diftance of the Vertical from the Meridian: for all which the Solution in Cafe 1. properly applied, will ferve.

On the South Side of the Zenith, when the *higheft* of the two Stars has the *leaft* right Afcenfion, they come to the fame Vertical on the *Eaft Side* of the Meridian; but when the higheft Star has the *greateft* right Afcenfion, they come to the fame Vertical on the *Weft* Side of the Meridian.

How to fix a Meridian-line by the Equality of the Time of Afcent and Defcent of a circumpolar Star toward the Meridian.

For performing this Problem it is neceffary to have a good Clock, or a good Watch, in the Room where the Obfervation is made, or in a Room adjoining to it. The Clock-cafe fhould be fet perpendicular by a Plummet, and the Back of it fcrewed firm to wooden Wedges, or to Holdfafts of Iron, driven tight in a Brick, or Stone Wall; or to an upright maffy Poft, or Beam, fet two or three Feet into the Ground below, and fupported higher up by inclining Stays on two or three Sides: for if a Clock is not fixed firm, but fet up againft an ordinary Wainfcoting, or is liable to any Shake by Perfons walking on the Floor, it will never be made to go exactly. There fhould likewife be fome Contrivance to prevent the lengthening or fhortening of the Pendulum by Heat and Cold. When the Clock has been placed perpendicular and immoveable, then it muft be exactly regulated to keep equal Time, which may be done in the following Manner.

Take notice of any Star that will be hid from your Sight, any Time of the Night, by a Chimney-head, the Corner of a Houfe, or a Poft fet firm in the Ground for that Purpofe. Make a fmall Hole in a Window-fhutter, or a Door, or in a thin Plate of Metal fixed in either of them, through

which

which the Star may be feen. A little before the Star will be hid, ftop
your Clock, or Watch, with the Second-hand at 60; write down the Hour
and Minute at which it was ftopt; continue looking to the Star through the
Hole; and the Inftant the Star difappears behind the Chimney-head, or
other Object, fet the Clock or Watch agoing. If a Watch is made ufe of,
it may be held in your own Hand, with your Finger at the Stopper, while
you look to the Star through the Hole. If it is a Clock, you muft have
an Affiftant ready to let go the Pendulum the Moment you call out, *Now*.
Next Night, about the fame Time, look through the fame Hole, and watch
the coming of the fame Star toward the fame Object, and the Moment it
difappears, ftop the Clock, or Watch, till you write down the Hour, Mi-
nute, and Second at which it was ftopt; and if the Time between the two
Obfervations fhewn by it, amounts precifely to 23 Hours, 56 Minutes, 4
Seconds, the Clock, or Watch has kept Time exactly. If the Time fhewn
by it is more than that, then it goes fo much fafter in a Day than it ought
to do: if the Time fhewn is lefs than that, then it goes fo much flower than
it fhould do to keep equal Time: and the Error in a Day fhould be noted
down, fo as to be allowed for afterwards, in cafe the Clock or Watch can-
not be brought precifely to equal Time, but may fall fhort, or exceed it, by
a certain Number of Seconds each Day. If there is Time enough, it is better
to let feveral Days, or a Week, intervene between the two Obfervations, and
for each Day elapfed, to allow 3 Minutes 56 Seconds for the Acceleration of
the Star's Revolution. That is, if the Clock or Watch goes equally, the
Star will difappear behind the Object 3 Minutes 56 Seconds fooner the fe-
cond Night, or in one Day, than it did the firft; in two Days, it will dif-
appear 7 Minutes 52 Seconds fooner; the fourth Night (or in three Days)
11 Minutes 48 Seconds fooner by the Clock or Watch than the firft Night;
and fo in Proportion for any Number of Days; or, a little more precifely,
according to the following Table.

I   When

When the Clock has been exactly regulated to go
equal Time, then pitch on a Star which does not set,
and is neither very near the Pole, nor too far from it.
If it is very near, it will change its Vertical flowly,
and the precife Time of its coming to it will not be
fo eafily diftinguifhed : if it is too far from the Pole,
it will come to the higheft Part of its diurnal Circle,
too near the Zenith to be obferved accurately at the
Plumb-line.   Some Star in the great Bear may be the
moft convenient.   Hang two Plummets with heavy
Bobs, fwinging in Water, near a large open Window,

Days.	M.	S.	3ds.
1.	3··	55··	54
2.	7··	51··	48
3.	11··	47·	42
4.	15··	43··	36
5.	19··	39··	30
6.	23··	35·	24
7.	27··	31··	18
8.	31··	27··	12
9.	35··	23··	6
10.	39··	19··	—

or Door, facing the North, and as nearly in the Direction of the Meridian
as you can ; let the Plumb-line next your Eye be fixt, and the other move-
able at pleafure from one Hand to the other.   The Eye fhould not be too
near the fixt Line, nor the fartheft Line of too fmall a Size ; for then they
will appear mifted, tranfparent and ill-defined, and the precife Time of the
Star's Appulfe will not be known ; but the Diftance of the Eye and the
Thicknefs of the Lines fhould, by previous Trial, be fuited to diftinct Vifion.
Stop the Clock at any Hour, with the Minute and Second Hands at 60, and
write down the Hour they point out. Near the Time that the Star comes in the
Direction of both Plumb-lines, let an Affiftant hold back the Pendulum of the
Clock, fo as to be ready to let it go when you call to him : keep both Plumb-
lines in one from your Eye, and the Moment the Star touches one Side of them,
call out, *Now* ; that your Affiftant may immediately let go the Pendulum of
the Clock.   Take care the Plummets be not fhifted in the leaft ; and, near
twelve Hours afterward, when the Star next approaches near to the Direction
of the Plumb-lines, take them in one from your Eye, and let your Affiftant
watch the Second-hand of the Clock, counting each Second audibly by the
Beats ; and the Moment you fee the Star at the fame Side of the Plumb-
lines as in the firft Obfervation, call out, *Now* : your Affiftant muft imme-
diately call out the laft fecond he counted, fo as you may know it and mark
it down, while he looks to the Minute and notes it down ; then write down
the Hour, Minutes and Seconds all together.   In the fame Manner, near
twelve Hours thereafter, when the Star approaches near to the Plumb-
lines on the other Side of its diurnal Circle, take the Plumb-lines in one
with your Eye ; let your Affiftant count the Seconds by the Beats of the

Clock

Clock, and the Moment the Star touches the fame Side of the Plumb-line as before, call out, *Now*; that he may repeat, audibly, the Second he counted laft, which you muft note down, while he looks the Minut', and notes it down. If the Time of the Star's Afcent on one Side of the Plumb-lines is exactly equal to the Time of its Defcent on the other, then the Plumb-lines hang precifely in the Meridian. If thefe Times are unequal, fhift the moveable Plummet a little toward that Side where the Star took the longeft Time; and begin the fame Operations again, and continue them till you find the Star takes equal Time on each Side of the Plumb-lines.

In Obfervations of this kind, where the Time is required to be known, it may be managed without an Affiftant, after fome Practice. For one may catch the Second from the Clock by his Eye a little before the Time of Obfervation, and continue counting the Seconds or Beats by the Ear, while his Eye watches the Star; and the Inftant it is hid, he fhould repeat the laft Second till he fees the Minute on the Clock, and then write down both together. Or, begin to count the Seconds by the Ear from the Moment of the Obfervation, till you can fee the Time fhewn by the Clock, from which fubtract the Number of Seconds you counted, and you will have the Time of the Obfervation according to the Clock.

If the Pendulum of the Clock is contrived to keep of an equal Length, notwithftanding the Variations of Heat and Cold; if it is not wuond up between the Obfervations, or does not ftop in the Time of winding; and if it is well regulated immediately before the Obfervations begin, and again verified by the diurnal Revolution of a Star when they are over; a very exact Meridian Line may be found this way. But fuch Clocks are rarely to be met with; the Operation is often tedious; and is practicable only in Winter, and when the Sun does not fet later than about half an Hour after four; for the Stars are feldom feen in Winter diftinctly, till the Sun is near an Hour and a half fet.

In this Operation, a Watch is managed much in the fame Manner as a Clock; only, when it is to be ftopt during the Obfervation, the Obferver may do it himfelf, by holding the Watch in both Hands, with his Finger at

the

the Stopper. When the Time is to be noted without ftopping the Watch, then, near the Appulfe of the Star to the Plumb-lines, an Affiftant muft count thc Seconds by the Motion of the Second-hand; and, when the Obferver calls out, *Now*, muft repeat audibly the laft Second he counted, that the Obferver may note it down, while the Affiftant looks to and notes the Minute.

Though other Methods of finding a Meridian-line than thofe above, except the laft, have been generally practifed and recommended by Aftronomers, yet it will be evident to Theorifts, efpecially fuch as are accuftomed to celeftial Obfervations, that when the Places of the Stars are exactly known, this important Problem may be performed more eafily, and with more Certainty, by means of a Plummet, *which adjufts itfelf*, than by any other Inftruments, or Obfervations whatever on the Sun. For it is well known, that in folar Obfervations, the Air, the Object, the Inftruments, the Obferver, may each occafion fome Inaccuracy, which the moft Expert cannot altogether avoid; but they are either quite removed, or eafily prevented, in our way, by the moft inexperienced Performer.

The polar Diftances and right Afcenfions of thefe fix Stars in 1770, were as follows: + fignifies increafing, — decreafing.

	Char. and Mag.	Diftance from the Pole.	Variation in 10 Years.	R. Afcenfion in Degrees.	Increafes in 10 Years.	R. Afcenfion in Time.	Increafes in 10 Years.
Northern Stars.		D. M. S.	′ ″	D. M. S.	′ ″	H. M. S.	′ ″
Pole Star	z. 2	0. 1. 56	— 3. 17	10. 44. 0	25. 0	0, 42. 56	3. 17
Firft in Tail of the G. Bear	a. 2	32. 47. 0	+ 3. 17	190. 45. 5	7. 0	12. 43. 0	0. 27
Middle of Cafiopeia's Chair	γ. 3	30. 32. 20	— 3. 17	10. 27. 16	9. 0	0. 41. 48	0. 35
Southern Stars.							
Head of the Crofs . . .	γ. 2	19. 9. 0	— 3. 18	184. 29. 42	8. 3	12. 19. 0	0. 40
Foot of the Crofs	α. 1	28. 10. 0	+ 3. 20	183. 29. 0	8. 3	12. 14. 0	0. 32
Head of the Phenix . .	α. 2	46. 30. 0	+ 3. 20	3. 43. 15	7. 30	0. 15. 0	0. 30

3

PROB.

PROB.

How to find the Sun's Amplitude at Rifing, or Setting, and from thence the Variation of the magnetic Needle.

Make the Needle level with the graduated Circle in the Box. Then, when the Sun's lower Edge is a Semidiameter above the Horizon, take the Bearing of its Center (from the N. or S. which ever is neareſt) through the Sights, making the Thread biſſect the Sun's Diſk, and that ſubtracted from 90°, will be the Sun's magnetic Amplitude, or Diſtance from the E. or W. Points by the Needle.

Next, calculate the Sun's true Amplitude for that Day, by the following Proportion.

As the co. ſine of the Latitude,
Is to Radius,
So is the Sine of the Sun's Declination at Setting or Rifing,
To the Sine of his Amplitude from the W. or E.

Which will be N. or S. as the Sun's Declination is N. or S: and the Diſtance in Degrees and Minutes between the true E. or W. and the magnetic, is the Variation of the Needle.

An eaſy and ſure way to prevent Miſtakes, which the Unexperienced are liable to in this Calculation is, to draw a Circle by Hand, repreſenting the viſible Boundary of the Horizon, and on it to mark the ſeveral Data by Gueſs; then by inſpecting the Figure it will eaſily appear how the Variation is to be found, whether by Addition or Subtraction, and on which Side of the North it lies. For Example:

PLATE I. FIG. XIV.

Suppoſe the Variation was ſought at Sun-ſetting. Draw by Hand a Circle N W S E, to repreſent your viſible Horizon: in the Middle of it mark the Point C, for your Station: from C, draw the Line C W, to repreſent the true Weſt; then on the North or South Side of that Line, according as the Sun ſet northward or ſouthward of the true Weſt, draw the

Line

Line C ☉, reprefenting the Direction of the Sun's Center at fetting, and another Line C w, for the magnetic Weft, either on the North or South Side of ☉, as it was obferved to be, and at its judged Diftance. Then by obferving the Situation of thefe Lines, it will eafily occur whether the magnetic Amplitude and true Amplitude are to be added, or fubtracted, to give the Variation ; and on which Side of the true North the Variation lies. In the prefent Suppofition, w ☉ is the magnetic Amplitude, and ☉ W the true Amplitude; ☉ W therefore muft be fubtracted from ☉ w to give w W the Diftance of the one from the other : and n, the magnetic N. 90 Deg. from w, muft be weftward of N, the true North.

This Method is fufficiently exact for finding the Variation ; but it is not exact enough for fixing a precife meridian Line : becaufe of the Uncertainty of the Refraction, and of the Sun's Center : but if the Sun afcends, or defcends, with little Obliquity, the Error then will be very little.

How to find the Sun's Azimuth, and from thence to find the Variation of the Needle.

Firft let the Latitude of the Place be exactly found. Next let the Quadrant be carefully adjufted for Obfervation. Then, two or three Hours before or after Mid-day, take the Altitude of the Sun's Center as exactly as poffible, making the vertical Wire of the Telefcope biffect the Sun's D.fk ; and, without altering the Plane of the Quadrant in the leaft, move the Telefcope vertically till you fee fome diftant fharp Object on the Land, exactly at the vertical Wire ; and that Object will be in the Direction of the Sun's Azimuth when the Altitude of its Center was taken. If no fuch Object is to be feen, let a Pole be fet up in that Direction, about half a Mile off, or as far as can be feen eafily.

Next calculate the Sun's Azimuth by the following Rule.

Add the Complement of the Latitude, the Complement of the Altitude, and the Complement of the Sun's Declination to 90° together, and take the half of that Sum, and note it down : fubtract the Complement of the Declination from the half Sum, and take the Remainder ; then take the Complement
plement

plement arithmetical * of the Sines of the Complement of the Altitude, and of the Complement of the Latitude, and add them together, and to them add the Sines of the forementioned half Sum and Remainder : half the Sum of thefe four Logarithms is the co. fine of half the Azimuth required. There-fore find by the Tables what Angle that co. fine anfwers to ; double that Angle, and that will be the Sun's Azimuth from the North.

If the Sun's Declination is S. in *North Latitude*, or N. in *South Latitude* ; in place of taking the Complement of the Declination to 90°, add 90° to it, and proceed as before.

In South Latitudes the Azimuth is found in the fame Manner ; only, the Sun's Azimuth is found from the S.

Then, to find the Variation, place your Needle below the Center of the Quadrant, fet it level, and find how many Degrees the Pole, or Object, in the Sun's Azimuth, bears from the North by the Needle ; and the Difference between that and the Azimuth found by Calculation, is the Variation of the Needle fought.

If the Sun afcends, or defcends with little Obliquity, a Meridian Line may be fixed pretty exactly this way, becaufe a fmall Inaccuracy in the Al-titude of the Sun's Center will not be fenfible in the Azimuth. But when the Sun does not rife high on the Meridian, this Method is not to be relied on when great Exactnefs is neceffary ; for then every Inaccuracy in Latitude. Altitude, and Refraction, occafions feverally a greater Error in the Azi-muth. To mark the Meridian-line on the Ground, place the Center of a Theodolite, or *Hadley*'s Quadrant, where the Center of the Quadrant was when the Sun's Altitude was taken, and putting the Index to the Degree and Minute of the Azimuth, direct (by waving your Hat towards one Side, or the other) a Pole to be fet up, making an Angle with the former Pole placed in the Azimuth, equal to the Sun's Azimuth found ; and that

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* The Complement arithmetical of a Logarithm is found thus : begin at the Left-hand of the Logarithm, and fubtract each Figure from 9, and the laft Figure from 10, fetting down the feveral Remainders in a Line ; and that Number will be the arithmetical Complement re-quired.

laft-

laft-placed Pole will be in the Meridian, feen from the Center of the Quadrant.

N. B. The Sun's Declination in the Tables muft be corrected by the Variation arifing from the Difference of the Time between your Meridian and that of the Tables; and alfo for the Variation of Declination for the Hours before, or after Noon, at which the Sun's Altitude was taken.

The two laft Problems are conftructed and explained in every Treatife of Navigation; it is therefore needlefs to be more particular here.

PART

MARITIM SURVEYING.

PART II.

Of the Procedure and Operations in surveying Sea-coasts, according to their various Circumstances.

CHAP. 1. A Stasimetric Scheme. 2. Procedure in surveying Coasts, under ordinary Circumstances. 3. In surveying Coasts unfavourably circumstanced. 4. Rocks and Shoals; Tides and Soundings; Descriptions; copying and reducing Draughts; Instruments. 5. Longitude; continuing a Meridian Line.

CHAP. I.

How to form a stasimetric Scheme of Points, by which the Distances along the Coast may be determined.

IN order to survey a Bay, Harbour, River, or any Part of the Sea-coast, with sufficient Accuracy and Expedition, three principal things are requisite. The first is, to measure a *fundamental Base-line:* the second, to form a *stasimetric Scheme* of Points, by which other Distances along the Coast may be determined: the third is, to delineate on Paper *a Figure similar to the proposed Coast.* The several Methods of finding the Length of a Base-line having been explained in Part 1. Chap. 3. the next is, how to form the *stasimetric Scheme;* which may be done in the following Manner.

PLATE II. FIG. I.

1. Having first taken a general View of the Place to be surveyed from an Eminence, in order to find out proper Objects for the Scheme, and to plan

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in

in your Mind the Procedure of the Survey; pitch on the fmooth Sand X Y for a fundamental Bafe-line, as near the Middle of the Harbour, or Part to be furveyed, as can be had conveniently: on it meafure the ftraight Line X Y with a Pole, or Chain, as directed p. 4; mark its Extremities on the Ground, and write the Number of Poles, or Chains, in a Field-book pre-pared for the Purpofe.

2. At X, with a Theodolite, take the Angles, that fome of the moft confpicuous and fharpeft Objects (fuch as Steeples, Towers, remarkable Tops of Hills, &c.) on each Side of the Bay, make with the Bafe-line; as Y X A, Y X B, Y X C, Y X D: and as many other Parts along the Coaft as are diftinctly feen, and may be judged convenient. If there are no re-markable Objects to be feen that are fmall enough, caufe Turrets, or Signals, of Stone or Turf, to be built for that Purpofe, on the moft convenient Hills or Eminences. Alfo, at Y, take the Angles X Y A, X Y B, &c. then take the Bearing of X from Y, with a good magnetic Needle and Sights: write thefe Angles diftinctly in the Field-book, together with the Name, or Defcription, of each Object, and the Part of it which you ob-ferve, fo that they may be known again when needed, or when you go to them: write down likewife, on which Side of the Bafe-line each Object lies, whether on the right or left, when you look towards the fartheft End of it.

3. Near the Middle of a Sheet of large Paper (fo as there may be room for laying the Protractor, and drawing out the Angles) draw the magnetic Meridian right up and down. In a convenient Part of that Line, mark a Point X, to reprefent one Extremity of the Bafe-line; and at X, make an Angle with the Meridian equal to the Bearing of Y from it. On that Bear-ing fet off the Length of X Y, in Miles and Parts of a Mile, taken from a Scale of equal Parts, not lefs than an Inch to a Mile.

4. From X and Y on the Paper, protract carefully, with a large Pro-tractor, the feveral Angles written in the Field-book; and alfo calculate trigonometrically the moft material Diftances: judge of the Accuracy of the Protraction by its Agreement with the Calculation; and if any of them differ, protract, or calculate thefe again till the Error is corrected, and the Points reprefenting the feveral Objects are marked in their proper Pofitions and Diftances on the Paper.

5. To

5. To verify thefe protracted Diftances, go to any of the Objects, as D, take the Bearing of X and Y, to find if they agree with the Protraction; if fo, then take the Angle X D Y, add it to the two other Angles of that Triangle, and if their Sum is 180 precifely, then is the Pofition of D exact: there alfo take the Bearings, by the Needle, of the other Objects; and if their Bearings from you agree with their Bearings from D on the Paper, then your feveral Operations have been rightly performed, and the ftafimetric Scheme is exact. If the Bearing of any of the Objects by the Needle differs from that of its reprefentative Point on the Paper, take the Angles of that Object again from the two Extremities of the Bafe-line, and protract them anew, till you difcover the Error, and find all agree: then, and no fooner, fhould you proceed to delineate the Coaft-line on the Paper.

Note 1. Very high Mountains, whofe Tops are often hid in Clouds, are on that account not fo convenient Objects for a ftafimetric Scheme, as Hills of a more moderate Height, which may be feen more frequently.

Note 2. As the Ufe of this ftafimetric Scheme is for finding the Diftances of other Parts along the Coaft, by one or other of the longimetrical Problems in Part 1. therefore great Care ought to be taken to get the Diftances and Pofitions of the Points in it exact: wherefore if any of the Objects lies too oblique to the Bafe-line, or is too far from it, to have its Diftance determined precifely; let *one* of the Angles only be taken at the Bafe-line, and the other from one of the Objects whofe Diftance is afcertained, and makes a more direct Interfection with it.

Note 3. If no level Sand can be had within the Bay, or Harbour, for a Bafe-line; then a fmooth Plane near it, on either Side, may be meafured, and the Diftances of the Objects on each Side of the Bay deduced trigonometrically from thence.

Note 4. If no Plane fit for a Bafe-line is in, or near, the Harbour to be furveyed, and if it is but a few Miles in Extent; then the Diftance of Objects properly fituated may be meafured by the Velocity of Sound (as above directed) and that Diftance made a Bafe-line, from which the ftafimetric Scheme may be deduced.

Note 5. If the Bay, or River is above eight Miles in Extent, and no fufficient Plane in, or near it; then take the Latitudes of two remarkable Hills, or Objects, at leaft 15 Miles afunder, and not above 45 Degrees from the Meridian; from thence find their Diftance in Miles and Parts of a Mile (by Prob. 2. page 12.) make that the Bafe-line, and from thence calculate and protract the Diftances in the ftafimetric Scheme.

The Form of a Field-book.

Meafured in a ftraight Line on the Sand on the S. Side of the Entry of Great-Harbour, from X (at the High-water Mark of White-point) to Y (at the Edge of the Grafs on Green-point) 416 Chains, 25 Links; each Chain 60 Feet long, and each Link one Foot; amounting to 4¼ Miles and 408 Yards more.

At X, (by the Needle) Y bears — W. $18\frac{1}{2}°$ N.

Angles taken at X, on the Side X Y. Y bearing W. $18\frac{1}{2}°$. N.

			Deg.	Min.
	a	Signal on Flat-hill - - - - - - -	23	24
	b	Steple of New-church, and Point of a Clay-		
Right Side.		cliff about a Mile beyond it - - - - -	36	15
	c	Sharp Rock on Black-head, and north End of a		
	d	Spring-tide Rock near the Middle of the Bay	41	48
	e	Caftle-ftrong, W. Corner - - - - - -	9	15
Left Side.	f	Low rocky Point N. of that Caftle - - -	11	54
	g	E. Gavel of Wood-houfe - - - - -	134	50

Angles taken at Y, on the Side X Y, X bearing E $18\frac{1}{2}°$. S.

			Deg.	Min.
	a	Signal on Flat-hill - - - - - - - -	64	40
Left Side.	b	Steeple of New-church - - - - - -	57	22
	c	Sharp Rock on Black-head - - - - -	95	16
		Hillock near Sandy-point, and Point of a high		
		rocky Cliff, fuppofed three Miles off - -	38	27
		W. Gavel of Cot-houfe - - - - - -	134	15
Right Side.	e	Caftle-ftrong, W. Corner - - - - - -	163	10
	g	E. Gavel of Wood-houfe - - - - - -	18	49
		Ben-more Hill, the weftmoft and moft tapering		
		Top; alfo a breaking Shoal about a League off	165	51

In

In taking the Angles at Y, take the fame Part of each Object which was done at X; and before protracting, prefix the fame fmall Letters to the Names of the fame Places, or Objects. Thefe Letters ferve to mark the feveral Directions of the Angles in protracting, fo that the Interfection of the correfponding Sides may be more readily found on the Paper.

C H A P. II.

Examples of the Procedure in furveying Sea-coafts, under the moft common Circumftances.

E X A M P L E I.

How to furvey a Bay, Harbour, or River, and to delineate the Coaft-line on Paper.

P L A T E II. FIG. I.

IN this Operation it will fave much Time and Trouble, if the Surveyor has been accuftomed to eftimate, by the Eye, fmall Diftances, fuch as a Mile, half a Mile, a Quarter, and 200 Yards, fomething near the Truth. This Dexterity may be acquired, fufficiently exact for the Purpofe it is to ferve, by frequently viewing with Attention fuch Diftances when actually meafured, and comparing other Diftances with the Ideas of thefe in the Memory; efpecially when the Nature of the Ground compared, and the Darknefs, or Clearnefs of the Weather, are nearly the fame.

Firft, form a ftafimetric Scheme of Points, as above delineated; and that the Points may be more diftinct, and the Paper not incumbered with a Number of unneceffary Lines, transfer the magnetic Meridian, and the feveral afcertained Points in the Scheme, to a convenient Part of a large Sheet of clean Paper (or of feveral Sheets pafted together) fo as there may be Room on it to contain and protract the reft of the Coaft: then draw a fmall Black-lead Circle, or Dots, round each of thefe Points to render them more apparent, and write near each the Name of the Object it reprefents. Next, divide the Paper all over into fmall Squares, by Black-lead Lines about an Inch afunder, drawn parallel, and perpendicular, to the magnetic Meridian.

Thefe

These Parallels ferve for laying the Protractor North or South, Eaft or Weft by the Eye readily, in any Point from whence a magnetic Bearing is to be drawn. If one Direction only of any other fharp Object has been taken, draw it out likewife from the Station at which it was obferved; and write its Name along that Line, with a (D:) before it, to fignify that it is the Direction of that Object; or an (L:) if it is the Limit of any Head, or Point. If Fig. 1. is the Harbour, the new ftafimetric Scheme will then look as in Plate II. Fig. 2.

In the next Place; With this Scheme of Points and angular Directions, go to any Station on the Shore whofe Place is marked on the Paper, as X, and there, with a good magnetic Needle, take the Bearing of a from it; draw it on the Scheme from X, the correfponding Point there, and judge its Diftance as near as you can; take that Diftance in your Compaffes from the fame Scale of equal Parts by which X Y was laid down; mark its Extent from X on the Bearing-line, and trace with the Point of your Compaffes on the Paper the Curvature of the Coaft between X and a, as exactly as you can: take alfo the Bearing of b from X, and draw it on the Paper. Next go to Y; at it take by the Needle the Direction of b, draw it on the Paper, and it will interfect the other Direction taken at X in b; trace the apparent Curvature between Y and b: take alfo the Bearing of a, and that drawn out will interfect its former Direction from X in the true Place of a; fketch the Curvature between a and b, and black-lead the whole from Y to X, which will finifh that Part of the Coaft-line. Next take the Bearing of c from Y, draw it out on the Scheme, and on that Line mark its judged Diftance, and with your Compaffes trace on the Paper the Curvature of the Coaft between them. At c interfect that Bearing by the Bearing of C, or D, and correct that Part of the Curvature which is next c, and pencil the Tracing between c and Y: then take the Bearing of d, draw it on the Scheme, mark its judged Diftance on that Bearing, and trace the Curvature between c and d with your Compaffes: take alfo the Bearing of g, draw it on the Paper, and mark it fo as to be found again when you come to g. At d take the Bearing of D, to interfect the former Bearing from c in d; correct the Curvature between them, and pencil it. Take alfo the Bearing of c, mark its judged Diftance, and trace the Curve between them: at e, by the Bearing of D, interfect its Bearing from d, correct the Curvature, and pencil as before. In the fame Manner, fix by magnetic Interfections

the

the Points f and g, and trace the Curvature and Windings of the Coaſt between them. But becauſe the Point h is more in the Way of Ships ſailing up the Bay than any of the former Parts between c and h, its Poſition ſhould be determined in the exacteſt Manner. Therefore at h, with a Theodelite, or Hadley's Quadrant, take the Angles A h B, B h C, and from thence (by Longim. Prob. 3.) find the Point of Station h; which will give its true Place independent of the former Stations. Next draw the magnetic Bearings of the Points i, k, l, m, n; interſect theſe Lines by the Bearing of C taken at each of them; delineate the Curvatures between them, and the Coaſt-line of the Bay will be ſo far finiſhed. In this Manner proceed along the whole Shore of the Harbour, *firſt* fixing the Place you ſtand on by Interſections of the Needle; but at proper Diſtances, and Parts that are of Conſequence to Navigation, let theſe be determined by two Angles taken more accurately, and protracted by one or other of the longimetrical Problems in Part I.

If all the Stations along a Coaſt are determined by magnetic Interſections, the natural Defects of the Needle will, in Time, produce ſenſible Errors. If all the Stations are determined by the Angles between three Objects (according to a Longim. Prob. in Part I.) though that in Strictneſs is the moſt exact Way, yet it would be much more tedious, confuſe the Draught with a Multitude of interſecting Lines and Arches, and anſwer no Purpoſe in Navigation better, nor in any Reſpect render a Draught more ſerviceable than if only ſome of the moſt material Stations, and principal Projections of the Coaſt here and there, were ſo determined, and the intermediate Parts found by Interſections of the Needle.

If, at any Part of the Coaſt, two, or three of the neceſſary ſtaſimetric Objects cannot be ſeen, becauſe of interpoſing Hills; or are not in a convenient Poſition for determining the Station wanted; go to ſome Eminence near that Station, from whence the Objects may be ſeen more advantageouſly, find the Point of Station on that Eminence by one of the longimetrical Problems in Part I. protract it on the Paper, and by it, with one or two of the other Objects, find the Station wanted on the Coaſt.

If at any Station, the Angle between two Hills, or Objects, is wanted, but interpoſing Eminences, or other Objects, hinder one of them to be ſeen; in that Caſe, go to the Top of the interpoſing Eminence till you

3

fee the Hill and Station from it, and exactly in a Line with them fet up two Poles; and the Angle between any of the Poles and the other Object, or Hill, taken at the Station, will be the fame with the Angle between the two Hills. Thus may the Angle, or Bearing of any Objects, be found from a Place where they cannot be feen, which will be neceffary or convenient on many Occafions.

Mountains, Rocks, and Stones, are frequently endowed with a magnetical Quality, which difturbs the Polarity of a Needle, and, if not adverted to, will create much Trouble. To prevent this, it is neceffary to carry two Needles always along with you, and to fet both down at each Station, beyond the Reach of each others Influence; if they both agree in the Bearing of the fame remote Object, it may be concluded that they are not difturbed by Magnetifm.

At every Station take Care to infert, and to diftinguifh in the Draught, the Appearances and Nature of the neighbouring Parts of the Coaft, fuch as rocky Cliffs, graffy Cliffs, fandy Shores, rocky Shores, &c. and remarkable Hills, Houfes, Trees, &c. but efpecialy fuch as may ferve for Landmarks to direct Ships through Channels, or to avoid Rocks and Shoals. The Hills and Houfes ought to be reprefented in fuch Profpects as will enable Sailors to know them when they are feen from the Sea, without regarding much the Diverfity of Perfpective which this will occafion in the fame Draught; for Uniformity ought always to give Place to Utility.

If the Survey is to be carried on without the Harbour, along the Coaft on each Side, it may be continued on the Foundation laid before, and by the fame Procedure, to as great a Diftance as the ftafimetric Objects can be eafily feen, and while the Angles they fubtend are not too acute to be relied on, or protracted with Certainty. Before this happens, it will be neceffary to pitch on other ftafimetric Objects as you go along the Coaft, to determine their Diftances carefully by one of the longimetric Problems, and make thefe fupply the Places of fuch of the former as are too remote; and by thefe laft, others ftill farther along may be determined, to ferve the fame Purpofe to a greater Extent. But let it be adverted here, that if too long a Series of Triangles is continued from one Bafe-line, the unavoidable Imperfection of Inftruments,

ſtruments, Obſervations, and Protraction, will, in Time, produce very ſen-
ſible Errors: therefore it is adviſeable to break off the Series at proper Diſ-
tances, and to lay a new Foundation by meaſuring another Baſe-line, and
proceeding by it as at firſt. When this is done, remember that two Objects,
or Points, in the firſt Draught, at a proper Diſtance and Poſition, be like-
wiſe included in the ſecond; that by theſe Points the two Draughts may be
eaſily joined together, and make one Map when it is needful.

When the Coaſt of a Bay, Harbour, or River is ſurveyed, or any confi-
derable Part of it, then find the Diſtance and Extent of all the Rocks,
Sand-banks and Shoals that lie near it; obſerve Leading-marks to them;
and Land-marks for avoiding them; ſound the Depth of the Water to,
round, and from each; and alſo along the Shore, as near to it as Veſſels
can, or ought to ſail. Alſo ſound particularly the ſeveral Places of An-
chorage, and take Land-marks, or Bearings for finding them, and inſert an
Anchor in the proper Part of the Draught, for pointing them out more
readily. Inſert alſo the Time of High-water on the Days of new and full
Moon, the ordinary Riſe of ſpring and neap Tides, the Direction of the
Stream of Flood, and what Irregularities may be obſerved in theſe, both
within and without the Harbour.

E X A M P L E II.

How to ſurvey an Iſland.

CASE 1. *If the Iſland has ſeveral conſpicuous Hills in it:* firſt meaſure a
Baſe-line on a Plane, or by two Latitudes. 2. On that Baſe-line form a
ſtaſimetric Scheme of Points, as was explained in Part II. Chap. 1. § 3.
Survey and delineate the Coaſt of the Iſland as directed for a Harbour in
the laſt Example.

P L A T E III. FIG. I.

CASE 2. *If the Iſland is but a few Miles long, and has but one remarkable*
Hill, or Object in it; as A, which may be ſeen from all, or moſt Parts of
the Coaſt: by one of the longimetrical Problems in Part I. find the Diſ-

tance of any of the Points, or Heads, in the Ifland (fuppofe B) from A. At B, take the magnetic Bearing of A, in Degrees and Parts of a Degree; lay down that Diftance on Paper according to the Bearing obferved; and draw black-lead Lines all over the Paper, parallel and perpendicular to the magnetic Meridian, about an Inch from one another. At B, with a Theodolite, or Hadley's Quadrant, take the Angles A B C and A B F; write them down firft in your Field-book, and then draw them out from the Point B: alfo take the Bearing of a and b by the Needle; judge of their Diftances from B; draw them, and fketch the Curve of the Coaft between you and them. Then go to C; there take the Angles A C B, A C D; write them down; add A B C and A C B together, fubtract their Sum from 180°, and the Remainder will be the Angle B A C; draw that Angle from the Point A, and it will interfect the Side B C in the Point of Station C. At C, take the Bearing of a, and that will interfect its former Bearing from B in the corrected Place of a: then fketch the Curvature between C and B, and pencil it. Next draw the Angle A C D; at D, take the Angles A D C, A D E; the former added to A C D and fubtracted from 180° will leave the Angle C A D; draw that Angle, and it will interfect the Side C D in the Station D: fketch and pencil the Curve between C and D. Then draw the Angle A D E, and the Bearing D c; fix the Point E by the Angle at E, and finifh the Bay between D and E as before. Go on in this Way from Point to Point round the Ifland, till the whole is finifhed, remembering to infert remarkable Cliffs, Houfes, or other Objects at each Station.

If at any Point, as G, or H, A cannot be feen; take the Direction of A from that Point, by fetting two Poles exactly in a Line between them, as mentioned in Page 72, and take the Angle between one of the Poles and the other vifible Object. By fuch a Procedure as this, the Circumference of any Ifland will be found to meet on Paper, without arbitrary Alterations.

When an Ifland is fmall, and great Exactnefs unneceffary; if the firft Diftance, or Bafe-line, is true, and long enough, all the other Diftances may be got fufficiently exact by Interfections of a good Needle, without any other Inftrument to take the Angles.

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When one Side, or Part, of the Island is delineated on the Paper, then find the Diſtance and Dimenſions of the ſeveral Rocks, Sand-banks, Shoals and Ledges along it; found the Depth of the Water towards and round each of them, and take Leading-marks on them, and Land-marks for avoiding them: found alſo along each Part of the Coaſt after it is delineated, as near the Shore as Veſſels can, or ought to ſail; and when the whole Coaſt is finiſhed, found round it a Mile, or more, from the Land.

EXAMPLE III.

How to proceed in ſurveying an extenſive Coaſt.

CASE 1.   If the Coaſt extends northward, or ſouthward, take, carefully, the Latitudes of two remarkable Hills, or Promontories along the Coaſt, as near the true Meridian as they can be found, and as far from each other as can be ſeen diſtinctly: ſuppoſe 20, 30, or 40 Miles.   From their Difference of Latitude, Bearings and Variation of the Needle, find their Diſtance in Miles and Parts of a Mile (by longim. Prob. 2. p. 12.) make the Chord of that Arc, or Diſtance, the Baſe-line, and by it form a ſtaſimetric Scheme of Points; one, or two of them, repreſenting remarkable and ſharp Objects. If one, or more, of the Objects lie off the Coaſt at Sea, it will be a Conveniency; for there will be fewer Objects to intercept the Sight of theſe. When the ſtaſimetric Scheme is verified, and transferred to ſome Sheets of clean Paper, and a Number of magnetic Meridians, and eaſt-and-weſt Lines, drawn over it, then begin to ſurvey and delineate the Coaſt, as directed in Example II.

It will ſometimes happen that no one proper Object is to be ſeen from *both* Ends of ſo long a Baſe-line, with which to form a ſtaſimetric Scheme; but if any remarkable intermediate Object, properly ſituated, is ſeen at one End of the Baſe-line, and the other End ſeen at *that* Object, its Diſtance may be found with equal, or rather more Accuracy, by taking one Angle of the Triangle, formed by the Baſe-line and Object, at that End of the Baſe-line where it is ſeen, and the other Angle at the Object; thence the third Angle is found; and the Diſtance of the Object.   Theſe three determined Diſtances will be ſufficient for finding all other Diſtances between

L 2   the

the two Extremities of the Base-line; and also for determining other stasimetric Objects necessary for continuing the Survey far beyond these Extremities.

Let it be observed, that if the Quadrant with which the Latitudes of the two Places were found, and the Observations, are good, a Base-line of 30, or 40 Miles measured in that Manner, is more to be relied on than such a Distance determined by a Base-line of three or four Miles measured on a Plane: because it is rare to find Planes so long without some sensible Irregularities in them; and more rare to meet with two so remote Objects sharp enough for taking the Angles at each End of such a Base-line with Precision. These two Sources of Inaccuracy may occasion a greater Error in a Distance of 20, or 30 Miles, than can be supposed when the Latitudes are carefully taken with a good Quadrant.

When the Survey has been continued by a Train of stasimetric Triangles a considerable Length beyond the Base-line, it will then be proper to discontinue the Procedure on that Foundation, and to measure a new Base-line; either on a level Plane, or by two Latitudes, as before; taking Care to have two determined Points common to both Draughts, for connecting them into one.

If the Instrument with which the Angles are taken does not give them minutely enough; or if the Objects that form the stasimetric Triangles are not sharp enough, Errors may be expected, and will undoubtedly become sensible in a long-continued Series of Triangles. How far they have actually taken Place in the Draught may be discovered by comparing the observed Bearings of distant Hills or Head-lands, whose Positions have been determined by former Observations, with their Bearings in the Draught: or, by comparing such moderate Distances as one can judge of by the Eye, with their protracted Distances on the Paper.

When a considerable Length of the Coast has been surveyed, the Soundings marked near it, and all the Rocks, Shoals, Banks, remarkable Hills, Buildings, Groves of Trees, and other Distinctions of the Coast inserted and expressed in the Draught; then sail along it, six, eight or ten Leagues from

the

the Land, according as it can be feen diftinctly; found the Depth of the Water, obferve the Setting of Tides and Currents, and fketch Views of the Coaft as you fail, inferting in them the Names of the moft material Hills, Heads, Entries of Rivers, Harbours, &c. fo that Seamen may know, by the Eye, where the principal Places on the Coaft lie, and how to fteer for them.

CASE 2.   *If the Coaft to be furveyed extends eaftward, or weftward*; chufe a remarkable Hill, or Head, near the Coaft, and another Hill, or remarkable Object up the Country, northward or fouthward; find their Diftance by meafuring a Plane, or by the Latitudes, and make that Diftance the Bafe-line; from thence form a ftafimetric Scheme of Points; and with it proceed to furvey and delineate the Coaft as before directed.

If any Part of a Coaft that extends eaftward or weftward is fo circumftanced, as neither to have in it a level Plane fit to be meafured, nor any Hill or remarkable Object up the Country, or lying off the Coaft, far enough diftant to become a Bafe-line by taking their Latitudes: in that Cafe, build a Wall or Turret, of Earth or Stone, on the moft confpicuous Part of the Shore; and another Turret three or four Miles from it up the Country, and fo large as to be feen five or fix Miles off, or farther: meafure the Diftance of the two Turrets by the Velocity of Sound, and make that a Bafe-line from whence to determine trigonometrically the Diftance of the other Stations and Signals fet up along the Coaft for that Purpofe: from thefe laft, find other Diftances: then, if you meet with no Plane fit to be meafured, nor any remarkable Hill or Object, at a fufficient Diftance and Pofition for determining a new Bafe-line by the Latitudes; meafure a new Bafe-line by Sound, and proceed as before. Such a Cafe as this is very rare; but when it happens, a good portable Telefcope, or Spy-glafs, will be found convenient, and fhould be provided accordingly.

That the maritim Survey of a Kingdom, or large Tract of Continent, may be carried on with Expedition and Accuracy together, it is neceffary one Superintendant, or Head-furveyor, expert in Theory and Practice, fhould have two Affiftants under him, who are capable of executing his Orders. *Their* Duty is, to conform to his Directions diligently and faithfully, as far as can be done; to omit no Part of the Coaft, nor neglect any Rocks,

Shoals,

Shoals, Channels, Tides, or neceffary Soundings; to be at Pains to get Information concerning them from the Inhabitants, or Pilots, wherever they come, but to infert nothing in their Draughts but what has been actually examined by themfelves; to keep a daily Journal of their Operations, Obfervations, and likewife of what Informations they may receive from others that have not been examined by themfelves.

The *Head-furveyor's* Duty is, to plan and direct the Procedure of the whole Survey; to order the Veffel, Boats and Men on the Service when and where he fees it neceffary; to chufe proper Planes and Diftances for meafuring fundamental Bafe-lines; to fee the Menfuration, or celeftial Obfervations himfelf; to pitch on proper Objects for the ftafimetric Scheme; and fee the Angles taken that determine their Diftances; to infpect the Calculations and Protraction; to verify the Scheme when protracted; to caufe a clean Copy of it to be made out for himfelf, and one for each of the Affiftants; to fend one of them to furvey on one Side, or towards one End of the Bafe-line; another on the other Side or End of it, and himfelf to remain with the Veffel that attends the Survey, and to furvey in that Neighbourhood; to examine their feveral Performances when they return to the Veffel; to compare the moft material Diftances in their Draughts with the Obfervations by which they were determined; to point out Miftakes, or Defects, and caufe them to be corrected; to infert the feveral Obfervations, Meafurements, Defcriptions, and Sailing-directions regularly in a Book; to join the feveral Parts of the Coaft, as they are compleated, into one Draught; and when that is of a fufficient Extent, to caufe a clean, diftinct Copy to be made of it aboard: then to fail in the Veffel to the next ftationary Harbour; to caufe Soundings, and ufeful Views of the Coaft to be taken by the Way, and fuch remarkable Objects on Land to be inferted in the Draught, as may have been omitted by the Affiftants. There will be no great Advantage in having more than two Affiftants under one Superintendant; for this would often occafion either Delays in waiting for one or other of them before the Scene of Operation could be fhifted; or elfe a fuperficial Infpection of their Performances.

Toward the End of Harveft, when the Days are turning fhort, and bad Weather may be expected more frequently, a Survey will be fooner difpatched, if the Examination of Shoals and Sand-banks, that lie at a Diftance

from

from the Land, is poftponed till the End of the following Spring ; and the Survey of the Coaft *only*, and the Soundings near it, or of Rivers and narrow Arms of the Sea, are taken in the Winter and Spring Seafons.

Though in general it is better that a confiderable Part of a Coaft be furveyed before the Soundings are taken near it, yet often both may be difpatched together with fufficient Exactnefs ; by making an Eye-fketch of the fmall Bays and Windings of the Coaft as you go from Point to Point in a Boat to determine their Diftances, taking the Soundings by the Way, and inferting them in the correfponding Parts of the Sketch as near as you can judge ; and at the fame Time marking down the Direction of the Boat, or on what Object her Head is kept, in failing or rowing from Place to Place ; and the Bearing of one or two Objects when the principal Soundings were taken : when that Part of the Coaft is furveyed, thefe Soundings may then be transferred to the Draught by the Bearings, and by the Direction in which the Boat was fteered. If any Shoals are met with, take Marks on them, or two contiguous Angles by *Hadley*'s Quadrant, and examine them more particularly afterward, when the Survey of the adjacent Part of the Coaft is finifhed.

EXAMPLE IV.

How to proceed in furveying a large Clufter of Iflands.

PLATE III. FIG. II.

Pitch on two remarkable tapering Hills, Rocks or other Objects, at a competent Diftance, as A and B, as near North, or South, of each other as you can ; and if a Line connecting them runs about the Middle of the Clufter it is the better. Find the Diftance of A and B, either by meafuring a ftraight Line on a Plane, or by their Latitudes, and make that the Bafeline : felect amongft the other Iflands one, or more, remarkable Objects on each Side of the Bafe-line ; as C and D ; of thefe form and verify a ftafimetric Scheme, as before directed. With this Scheme go to one of the Iflands, and by longim. Prob. 4, or 7, find the Diftance of two proper Parts, or Points in it ; make that a Bafe-line for furveying it, as explained in Example 2. Do the fame for each Ifland, founding the Channels between them, and obferving the Setting and Strength of the feveral Streams of Tide as

3   you

you pafs and re-pafs, taking Notes of all and inferting them in the Draught at the Time they are obferved. When all the Iflands are furveyed and Channels founded, and every neceffary Particular is inferted in the Draught, then fail round the whole, between four and ten Leagues from the Land, and found the Depth at that Diftance, and draw Views of the Land as you fail.

If the Iflands extend northward and fouthward in a narrow Chain, (as in Fig. 3.) and are fo fmall, or fo uneven, that no fufficient Bafe-line, for the whole, can be meafured on either of them ; then find by their Latitudes the Diftance of two of the moft confpicuous Hills, or Rocks, that are fituated along one Side of the Clufter, and at a fufficient Diftance from each other, as A and B. At A and B with *Hadley*'s Sextant, or a Theodolite, take the Angles B A C, B A D, A B C, A B D, and from thence and the Side A B, find the Places of C and D any two remarkable Objects on the other Side of the Clufter of Iflands, which may make the Angle B A C and A B D as near to right Angles as may be conveniently had. From any three of thefe Points the Pofition of a Place on any of the Iflands may be found; or by Interfec- tions of the Needle from *two* advantageoufly fituated; and each Ifland deli- neated feparately, as before directed.

C H A P. III.

Examples of the Procedure in furveying Sea-coafts under unfavour- able Circumftances.

E X A M P L E I.

How to furvey fmall Iflands that extend Eaft or Weft in a long narrow Train.

P L A T E III. F I G. IV.

IF the Iflands are fmall, and extend eaftward or weftward in a long narrow Train, as Fig. 4. then no fufficient Bafe-line will be found either by meafuring a Plane, or by the Latitudes of any two Iflands : in that Cafe, if the whole Extent of the Iflands is not above 12 or 15 Miles, a Bafe-line

may

may be meafured by the Velocity of Sound, a ftafimetric Scheme protracted from thence for determining the Diftances of the feveral Iflands from one another, and each furveyed feparately, as before directed. But if the Iflands extend above 15 Miles in Length, fuch a Procedure will not be found fufficiently exact, becaufe a Diftance cannot be meafured by Sound with Precifion : then the following Method is more to be relied on.

Pitch on the moft remarkable Head, Hill, or Object that is to be found near the Middle of the Range of Iflands, as X : find its Latitude, and the Variation of the Needle there. Then five or fix Leagues northward, or fouthward of X, anchor a Veffel, as at V : on a prefixed Day, let the Latitude of the Veffel be taken aboard with *Hadley*'s Quadrant, as exactly as poffible : and at the fame Time, while the Veffel remains fteady in the fame Place, let the Angles X V C, X V D, be alfo taken with *Hadley*'s Sextant, and as many more Angles between them as there are remarkable Objects to be feen. About Mid-day, while the Sun's Altitude is taking on board, let one Affiftant at X find the magnetic Bearing of the Veffel from thence ; and alfo fet up a Pole half a Mile, or a Quarter of a Mile from it, exactly in the Direction of the Veffel ; and let the Place of the Pole be marked on the Ground, for future Ufe. Let two other Affiftants be ftationed one at A, and the other at B, four or five Miles on each Side of X, and there mark the Direction of the Veffel from them at Mid-day, by Poles in the Ground as was done at X, fo that the Angles V X A, V X B and X B V, X A V, may be taken afterwards at Leifure, though the Veffel is removed. Find the Diftance of X V (by longim. Prob. 2.) make that the Bafe-line ; on it protract the feveral Angles obferved on Shore, and aboard, and form a ftafimetric Scheme of Points ; in which the Stations X, V, A, B, will be determined ; and alfo one Direction of C and D, and of the other Objects obferved at V. From the Angles which two, or three of thefe Objects fubtend, the Diftances of the other Iflands, or of any Station in them, may be found, and each Ifland furveyed feparately.

If the whole Extent of the Iflands cannot be included in the Angles taken at V, the fame Operations muft be begun again where the former ended, and the reft of the Iflands furveyed in the fame Manner.

M   E X A M-

EXAMPLE II.

How to proceed in surveying a Coast covered with Wood, or Bushes, so that in-land Objects cannot be seen from the Shore.

PLATE III. FIG. V.

Case 1. *If it is a River, Bay, or Habour* ; find ftafimetric Objects on the Side oppofite to that which you are to delineate, and by thefe determine your ftationary Diftances by two Angles, or by Interfections of the magnetic Needle.

Case 2. *If it is an open Coaft, that has no Land oppofite to it near enough.* 1. Meafure a Bafe-line on a Plane, or by two Latitudes, and from thence find the Diftances of three remarkable in-land Hills, or Objects, as Y, R, W, that may be feen from a Boat at Sea, over the Trees ; and protract a ftafimetric Scheme on Paper including thefe three Objects. If three remarkable Objects cannot be had ; two conveniently fituated for magnetic Interfections along the Coaft will ferve.

2. Prepare eight Poles, each with a flag flying at its Top for Signals ; two of the Flags white, two red, two yellow, or ftriped, and two black : the white to reprefent one of the ftafimetric Objects, the red another, the yellow or ftriped a third, as fhall be agreed on between the Surveyor and his Affiftant ; the black any new ftafimetric Object, whofe Place may be found neceffary to be determined as the Survey goes on. Let thefe Colours be written on the ftafimetric Scheme, each at the Point, or Object, fignified by it ; and a Copy of the Scheme given to the Affiftant to direct him, and prevent Miftakes ; together with four of the Signals, each of a different Colour : the other four are to be carried along with the Surveyor.

3. At the firft Point, or Station on Shore, whofe Diftance is to be determined, as A, let the Surveyor fet up a Signal of a Colour indicating what ftafimetric Object is to be firft obferved, as Y, or yellow. Then the Affiftant muft go off in a Boat to X, as far from the Shore as to fee the ftafimetric Objects over the Trees, and take that Signal in a Line with the Object it denotes, keeping the Boat fteady at Anchor in that Place, and putting

up

up a Signal of the fame Colour with the Surveyor's, to fignify that the Boat is then in the right Place. Let the Surveyor then take exactly the magnetic Direction of the Signal X in the Boat; which will alfo be the Direction of his Station B from the indicated ftafimetric Object Y. Let it be drawn out on the Paper from its proper Point Y, and a Signal of another Colour R, fet up in the Place of the former, to fignify to the Affiftant to move the Boat till he takes that Signal in a Line with the Object R it reprefents; and there let the Affiftant, when ready, put up the like Signal at Z, and keep the Boat at reft till the Surveyor has taken its magnetic Direction, and drawn it on the Paper; which will interfect the former Direction in the Point of Station A, on the Shore.

4. Let the Surveyor then take the magnetic Direction of the next Point of Land B, along the Shore; draw it on the Paper; eftimate its Diftance by the Eye; mark that Diftance on the Line of Direction; fketch with the Point of his Compaffes the Figure of the Curvature of the Coaft between the two Points A and B; take down his Signal and wave it, for a Sign to the Boat to move towards the next Point B, on the Coaft.

5 When the Surveyor comes to that Point, let him put up a Signal W, or White, intimating what ftafimetric Object the Affiftant is to take in a Line with it; which when he has done, let the Affiftant fet up the like Signal in the Boat, and keep it fteady at Anchor till its Bearing is taken on the Shore; which will interfect the Line of Direction taken at A the firft Station, in the corrected Diftance of B the fecond Station: let the Curve of the Coaft between them be alfo corrected, and drawn with Black-lead, and the Coaft-line between thefe two Points of Land will be finifhed.

Let the Diftance of the next Point C be determined, and the Coaft-line fketched, in the fame Manner; and go on thus till the ftafimetric Objects can be feen by the Surveyor on Shore, when there will be no Occafion for the Boat.

If any of the ftafimetric Objects fhall happen to be hid from the Affiftant's Sight by interpofing Hills; he muft then firft fet up the Surveyor's Signal, and above it fet up that Colour which points out fome other ftafimetric Object that is feen: which when the Surveyor obferves, he muft fet up

another

another Signal of the fame Colour above his former one, and then take the Direction of the Signals in the Boat; which will be the Direction of his Station from the Object reprefented by the uppermoft Colour.

When any of the ftafimetric Objects begins to difappear, or to be too remote, or oblique, for Accuracy; then, when the Surveyor is at a proper Station, the Affiftant muft fet up the black Signal; to fignify that the Place of a new ftafimetric Object is to be determined. The Bearing of the black Signal taken when the Boat is at Reft, and drawn out from the Surveyor's Point of Station, in the oppofite Direction, will be one Direction of the new ftafimetric Object. When the Surveyor comes to another Station proper for another Interfection, the black Signal muft be fet up again by the Affiftant: and when the Boat is at Reft, the Surveyor is to take its magnetic Direction, which will interfect the former in the Place of the new ftafimetric Object; which muft continue to be pointed out thereafter by the black Signal; till, by Agreement, it fhall be changed for another Colour, that the black Colour may be again referved for another new Object, in cafe it fhall be neceffary.

As the Affiftant goes along the Shore in the Boat, he may at the fame Time found the Depths of the Water, and mark them on an Eye-fketch of the Coaft; or infert them by their Bearings from the Stations, and other remarkable Parts of the Coaft.

For this Manner of Surveying, it is neceffary that the Affiftant fhould be tolerably acquainted with the Bufinefs, that he may be capable of making a proper Choice of Objects, and Stations for determining their Diftances.

This Method of furveying a Coaft is fometimes neceffary; and though not fo exact as when the Angles can be taken with a Theodolite, or *Hadley's* Quadrant; yet when the ftafimetric Objects are advantageoufly fituated, and the Coaft fo furveyed is not very extenfive, it will be found fufficiently exact for the Purpofes of Navigation. If any particular Part of fuch a Coaft requires great Exactnefs, then three Affiftants, and three Boats, muft be employed at the fame Time; each muft have the fame Sort of Signals, and they muft take the Surveyor's Signal bearing on three different ftafimetric

Objects

A Coast extending Northward & Southward to illustrate Example III. Page 85.
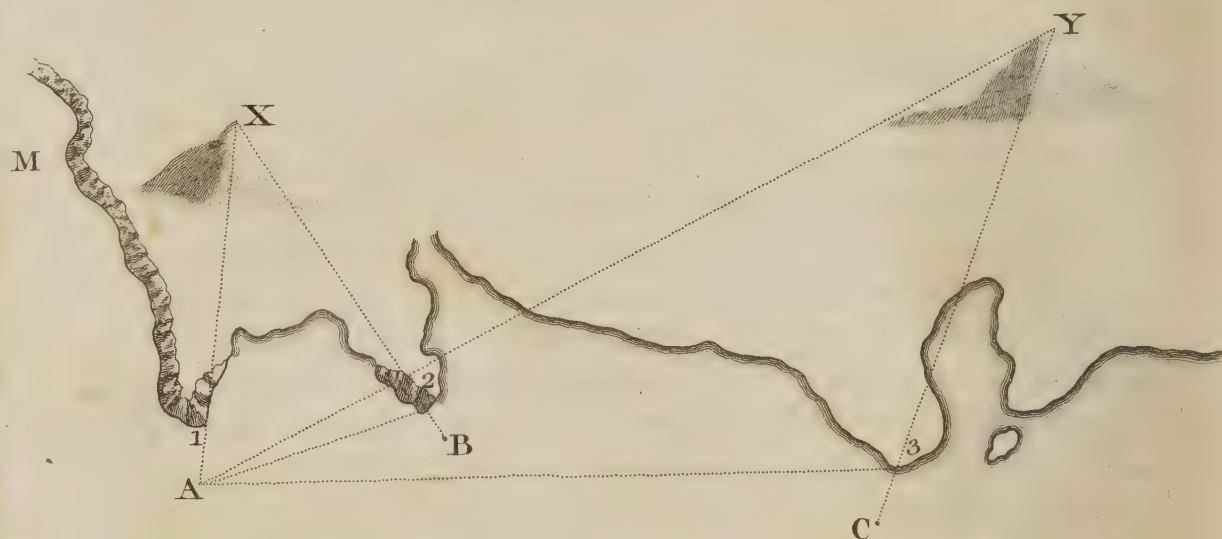
X and Y are two tapering Hills (mentioned in Article 2) whose Bearing may be taken at M, and their Distance found by their Latitudes and Variation of the Compass.

1, is the remarkable Promontory at which the Delineation begins (mentioned Article 5) 2 and 3, the second and third Points of the Coast (mentioned Art. 6 and 7)

A, B, C, are the three Stations of the Boat near these Points.

The dotted Lines are Compass-bearings taken at the several Stations, by whose intersections the Places of the Boat and Distances of the Points of Land are determined.

Objects at once; by which Means he may take the Angles between them by a Theodolite, or by *Hadley*'s Quadrant, which will be the fame with the Angles between the three ftafimetric Objects; and from thence may find the Place of Station precifely, by longim. Prob. 4.

If there is any Stream of Tide, or Breeze of Wind, where the Boat lies, it will not be kept fteady by one Anchor only, but muft be made to ride by two, in order to continue in the fame Place while the Surveyor makes his Obfervations on Shore.

EXAMPLE III.

How to furvey a Coaft, without going afhore on it.

There are fome Coafts where it is impracticable to land for a continued Swell and Surf on the Shore; and others, where the Barbarity of the Inhabitants renders it unfafe; the Survey of fuch Places muft be made altogether at Sea; and may be done in the following Manner.

CASE I. *If the Coaft extends northward and foutbward.*

1. Find the Variation of the Compafs.

2. Chufe two remarkable tapering Hills, or other fharp Objects, 20 or 30 Miles afunder, and as near the fame Meridian as they can be had; but fo fituated, that by failing along the Coaft or into a Bay, or River, one of them may be taken in a Line with the other, fo that their mutual Bearing may be exactly taken with a good amplitude Compafs.

3. The Variation being found, bring a Ship to an Anchor right Eaft, or Weft, from each Hill or Object, on different Days, and there obferve their Latitudes with *Hadley*'s Quadrant; which will be the Latitudes of the two Hills refpectively.

4. From thefe Latitudes and their Bearing, find the Diftance of the two Hills, by longim. Prob. 2. and protract a ftafimetric Scheme, in which thefe two Points will be given.

I

5. In

5. In a rowing Boat of 8 or 10 Oars, and in moderate Weather, go as near to some remarkable projecting Point, or Promontory, as you can with Safety; there anchor your Boat, and with an amplitude Compass, constructed and balanced so as to be as little affected by the Motion of the Boat as possible, take the Bearing of the two stasimetric Objects; draw these out from their corresponding Points on the Scheme, in the opposite Direction, and their Intersection will be the Place of the Boat. Take the Bearing of some remarkable Part of the Point, or Promontory next you; judge its Distance as near as you can; draw that Bearing on the Paper from the Point found for the Boat's Place; and on it mark the estimated Distance of the observed Part of the Point or Promontory; which will be one Point in the Coast to be surveyed, and sufficiently exact for the Purposes of Navigation; the Error being only what may arise from estimating a Distance that is not above a quarter or half a Mile off.

6. In the Boat, take the Bearing of the next Point along the Coast, from the Point or Promontory determined; draw it on the Paper; mark its estimated Distance on that Line; and with the Point of your Compasses trace on the Paper the Figure of the Coast between these two Points of Land.

7. Go to the Point last observed, as near as you can; take its Bearing from one of the stasimetric Objects, which will intersect the Line of Direction from the first Place of Anchorage in the corrected Distance of the second Point along the Coast; correct also the Figure of the Coast, and pencil it; and lastly insert remarkable Objects on the Land, and Diversities of the Coast between the Points, together with the Rocks observed, and Soundings taken by the Way. Take the Bearing of the third Point, mark its estimated Distance, sketch the Curve of the Coast, and correct both when you are at that Point as before; and go on in this Manner, from Point to Point, till the whole is finished.

Though this Method of Surveying is less perfect than any of the other Methods, yet if the Card of the Compass can be made to stand at Rest in the Boat, either by Art, or the Smoothness of the Sea, a Draught of a Coast may be made in this Manner, or of Bays or Harbours in it, which

will

will give a diftinct Notion of them, and prove a pretty good Direction to Shipping, either along the Coaft, or into thefe Bays or Harbours.

CASE 2. If the Coaft extends eaftward and weftward, then two ftafime-tric Objects muft be chofen, which lie about N E or S W from each other, and alfo their Bearing and Latitudes found, in order to find their Diftance, and form a ftafimetric Scheme for carrying on the Survey in the fame Man-ner as before.

E X A M P L E   IV.

From a Veffel at Anchor in the Mouth of a Harbour, how to fketch the Harbour fpeedily, as far as can be feen.

Suppofe Fig. 6. in Plate iii. is the Harbour, and the Veffel at V : take the Bearing of any remarkable Part D, right up the Harbour ; guefs as near as you can to its Diftance ; draw out the Bearing on Paper, and by a convenient Scale mark on it that judged Diftance. In the fame Manner, mark a Point for the Bearing and judged Diftance of C : then draw between C and D on the Paper, the Curvature, or Windings of the Coaft, as they appear to the Eye. Next take the Bearings and judged Diftance of the Point B, and draw the Irregularities of the Coaft from B to C, and to F. Do the other Side of the Harbour from A to D and to G in the fame Man-ner, and the Figure on the Paper will have an apparent Refemblance to the Harbour, exhibit its Dimenfions fomething near the Truth, and fhew the true Courfe into it, if there are no unperceived Rocks or Shoals in the Way. Next, infert in the Draught the moft remarkable Appearances of the Coaft, the Houfes, Hills, Trees, Forts, &c. and fuch Rocks or Shoals as can be feen while you remain there. In failing to or from the Harbour, the Lay of the Coaft, on one, or both Sides of the Entry ; and within the Harbour from B to C, and from A to E, may be corrected by the Bearings.

This Method of fketching a Bay, or Harbour, though far from being exact, will give fuch an Idea of it as may be of Service on fome Occafions ; and therefore fhould not be neglected when there is no Opportunity of doing it more exactly.

E X A M-

EXAMPLE V.

How to make a ferviceable Draught of a Harbour by a Compafs, or magnetic Needle, only.

PLATE II. FIG. I.

Go to fome Eminence where the whole, or a great Part, of the Harbour may be feen, and felect two confpicuous fharp Objects, as tapering Hills, Steeples, Chimney-heads, &c. as A and C, at a competent Diftance from each other, and conveniently fituated for a bafe Line; (if no fuch fharp Objects are to be found, put up Signals on the Hills, or Eminences;) take their Bearing in Degrees, and Parts of a Degree by the Needle, or Compafs, which fhould be provided with Sights, and graduated for that Purpofe; and eftimate by the Eye the Diftance of C from A, as near as you can judge. At A and C take the Bearing of B, and of any other remarkable Object D, on the other Side of the Harbour; and from thefe Data protract a ftafimetric Scheme on Paper, wherein the Points A, B, C, D, will have the fame magnetic Directions and proportional Diftances as the Object they reprefent.

With this Scheme go to any adjacent Point of Land in the Harbour, as X; there fet down your Compafs, or Needle; take the magnetic Directions of two of the ftafimetric Objects that are moft advantageoufly fituated; draw them out from their refpective Points on the Scheme, and their Interfection will be the Point of Station X. At X take the Bearing of the next Point Y; guefs its Diftance from you; take that Diftance from the Scale; mark it on the Bearing-line, and trace on the Paper with the Point of your Compaffes the Curve of the Coaft between X and Y; take alfo the Bearing of a and b, and of fuch Rocks and Shoals as may be feen along the Coaft, and draw them on the Paper. Then go to Y; there take the Bearing of A, or of any other of the ftafimetric Objects that may make a more direct Interfection; draw out its Direction, and its Interfection with X Y will be the corrected Place of Y. By the Bearing of b and of a, correct likewife their Pofitions; then the Curve of the Coaft between X and Y may be traced with Black-lead more exactly, and remarkable Houfes, Trees, &c. inferted,

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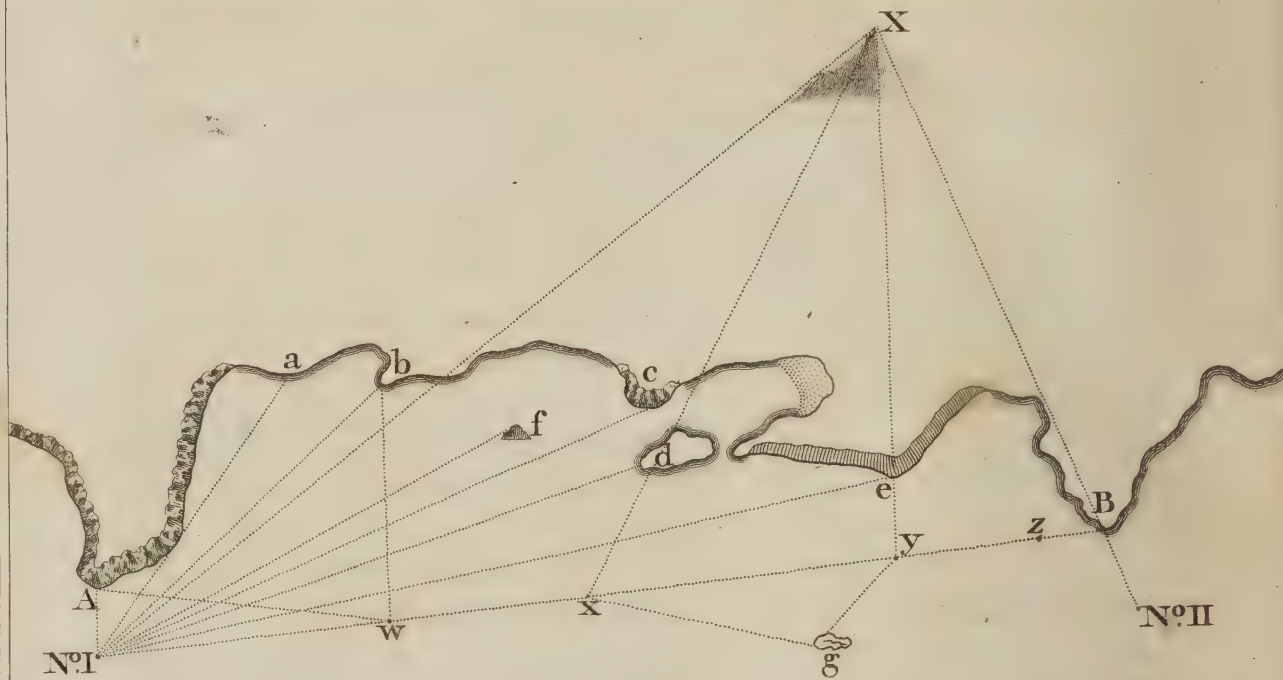
From A *to* B *is the Extent of Sketch* 1.st X, *an inland Hill determined by its Bearing at* N^o.I, *and* N°.II, *or more advantageously at* y.

N^o.I, *is the first Station, or Anchorage, of the Ship; its Distance from* A *is by Estimation.*

N°.II, *the second Station, or Anchorage; its Distance from* B *Estimated, or determined by two Bearings of Objects advantageously situated.*

IA, Ia, Ib, &c. *the Bearings of the several Points, Rocks &c. whose Distances from* N^o.I, *are all to be marked, at first, by Estimation, and the Coast faintly sketched between them.*

IB, *the Ships Course, or the Line in which she is supposed to sail toward the second Station, measured by the Log.*

w, x, y, z, *are Distances on that Line, measured by the Log; at each of which some intersecting Bearings are taken and drawn out while the Ship is under Sail, for correcting the former Estimated Distances of the Points, Rocks &c. and then sketching more exactly the Figure of the Coast between the several Places.*

J. Lodge sculp.

and the Diverfities of the Coaft between X and Y marked.   Proceed in the fame Manner from Point to Point till the whole Coaft-line of the Harbour is delineated.   If any more ftafimetric Objects become neceffary, let their Places be determined by magnetic Interfections drawn from two of the former Objects.

Next, by Interfections of the Needle taken on Land, or of the Compafs on Sea, find the Places and Extent of the feveral Rocks, Shoals and Sand-banks in and near the Harbour, take Marks for avoiding them, and found the Depth of the Water round them, and in other Parts of the Harbour; and mark the beft Anchorage.

Such a Draught as this of a Bay or Harbour neither requires much Skill nor Time to execute; and though not exact in the Diftances, exhibits a juft Reprefentation of the Place; and will be found fufficient for directing Veffels in and out without a Pilot, if the Channel is not *very* intricate.

E X A M P L E VI.

How to fketch a Coaft in failing along it.

1. Prepare a Sheet of large Paper, with parallel Black-lead Lines and Perpendiculars croffing them all over, as in a ftafimetric Scheme.   Prepare alfo, in a Book, an *Obfervation Table*, in which is to be wrote diftinctly and re-gularly, the feveral celeftial Obfervations, Bearings, Diftances meafured by the Log-line, Rocks, Shoals, Soundings, Overfalls, Races of Tide, and other Remarks that may be made along the Coaft.   The Table may confift of feven or eight Columns, difpofed in the following Order.

Obferva-

OBSERVATIONS IN NAVIGATING THE COAST OF ———

SKETCH I.

From Cape ——— to the Point ———, being ——— Miles measured by the Log. The Course from Station I. to II. being S ¼ W.

Year, Mon. and Day.	Mer. Alt. of the Sun.	Bearings at Station I.	Time and Distances sailed from St. I.	Bearings and Soundings taken at these Distances.	Bearing of Rocks, Shoals, Overfalls, and their estimated Distances, when in a Line with Points or Heads on the Coast.	Remarks on the Tides, and on the Nature and Dimensions of the Rocks, Shoals and Anchorage.
	D. M.		H. M. Mi.	Fath	Points and Heads Mi.	
1774 Jan.		A W. 17° N. a W. 22 S.	1 20 ¾ 11 45 4	A N. 5° W. } 21 b W. 20 S. }	c, and Rock. W. 7° N. 2½ d, and Hill. S. 19° W.	This Rock dries at low Water, and seemed 100 Yards in Length from N E. to S W. a Leading-mark to it is,

2. Let four expert Persons be appointed; one to take the Bearings exactly with an Amplitude Compass; one to oversee the Running-out of the Log-line, and to keep an Account of the Ship's Way, so as to be able readily to tell the Distance she has run, when required; the third to attend the heaving of the Lead, to write down the Soundings, and the Bearings of one or two Heads, Points, or remarkable Parts of the Coast taken at each Depth: the fourth, a Draughtsman, to draw out the necessary Bearings and Distances, and to delineate the Figure and Windings of the Coast at the several Stations, and to correct their Forms and Dimensions while the Ship is sailing along the Land.

3. Begin to take the Sketch, if it can be done, off some remarkable Promontory, or Point, that extends farther out than the rest of the Coast, and may intercept and turn off the principal Stream of Tide, so that there may

be

be little Stream where the Ship's Way is to be firft meafured by the Log. Bring the Ship as near the Point as can be done with Safety; there drop Anchor, if the Depth of the Water and the Ground are proper for it; if they are not, make the Ship *lie to* as fteadily as poffible.

4. On a convenient Part of the prepared Paper make a *Dot* to reprefent the Place of the Ship; draw a fmall Black-lead Circle round the Dot to make it more confpicuous, and mark it with Nº I. for the firft Station. Then take the Bearing of the Point, or Promontory you lie off; draw it out with a Protractor from the Dot; eftimate its Diftance by the Eye as exactly as you can; take that Diftance from a proper Scale of equal Parts, mark it on the Bearing-line with a Dot, and with the capital Letter A. Next take the Bearing of the fartheft Point, or Promontory, which is feen diftinctly, and is intended for the Limit of the firft Sketch; draw it out from Nº I; eftimate its Diftance by the Eye; take it from the Scale, and mark it on the Bearing-line with a Dot and with the capital Letter B. Take alfo the Bearings, and eftimate the Diftances, of all the Points, Heads, Inlets of Rivers or Harbours, Rocks, Corners or Heads of Bays, that are feen between the two Points A and B; draw them out and mark them with the fmall Letters a, b, c, &c. as far as they are feen with any Diftinctnefs.

5. Sketch faintly (fo as it may be eafily rubbed out when it is to be corrected afterward) the Figure of the Coaft between the feveral Dots; as from A to a, from a to b, from b to c, &c. as far as two or three Miles; or only as far toward B as you have a diftinct Sight of the Bays, Irregularities, and Dimenfions of the feveral Parts of the Coaft, and let the reft be fketched as you fail paft them, after their Diftances have been corrected by the Ship's Run meafured by the Log.

6. Look for fome confpicuous tapering Hill, Building, Steeple, or Grove of Trees, up the Country, and feveral Miles diftant from the Shore, and fituated as far along the Coaft toward B, **or** beyond it, as can be found; take the Bearing of that Hill, or Object exactly, draw it on the Paper; and when another Bearing of it is taken at a proper known Diftance from the Station I, its Pofition will then be determined on the Draught by the Interfection of thefe two Bearings, and will ferve for correcting, or determining the Diftances of Points, Promontories, Bays, &c. along the Coaft.

7. While the Ship lies at Station I. off A, let the Latitude be obferved, if there is an Opportunity, either by the Sun or Stars. Then get the Ship under Way, and fail in a ftraight Line for the fecond Station off B; meafure the Ship's *Run* carefully by the Log, and keep an Account of the Time by a Watch as you fail; that when you are off any of the Heads, Points or Openings marked with the fmall alphabetical Letters, their Diftance may be known more exactly and corrected: Correct alfo, by the Way, the Figures and Dimenfions of thofe Parts of the Coaft which were imperfectly feen and fketched at Nº I. Alfo, found the Depth of the Water by the Way, and at each Sounding take the Bearing of the firft Point A, or of the laft Point B, and of one or more of the Heads, or Points on the Coaft; and likewife of the inland Hill, or other Object, in order to determine afterward the Places of the feveral Soundings, and to difcover whether the Ship is carried out of the ftraight Courfe by Streams of Tide, Currents, or Lee-way, and to correct that Deviation. Let fuch Rocks, Shoals, Overfalls, or remarkable Streams of Tide as are met with, have two or three Bearings taken of them when they appear in a Line with any of the Points, Heads, or Iflands in the Draught, and their Extent eftimated by the Eye; and all wrote in a Book, to be inferted in the Draught more correctly afterward; and if there is an Opportunity, to be more particularly examined another Time.

8. When the Ship has got to the Head, or Point B, the Limit of the firft Sketch, drop Anchor; or bring the Veffel *to*, as at Nº I; write at the Top of the *Obfervation Table* the Diftance between A and B, as meafured by the Log; and write in the Table all the intermediate Diftances fo meafured; and likewife the Obfervations, Bearings, Times of them, Diftances, Soundings, and Remarks; all of which muft be referved for future Ufe, when the Sketch undergoes another Correction.

9. At Station II. take the Bearing of the inland Hill, or Object, one Direction of which was drawn out from the firft Station, and thefe two Bearings will interfect in the Place of the Hill; which will then ferve to correct the Pofition of fome Parts between the firft and fecond Stations, and to determine by Interfections the Pofition of Heads, Points, and other Parts of the Coaft between the fecond and third Station; and verify, or correct, their Pofitions meafured by the Log.

Take

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Take alfo the Bearing of the Top of fome other confpicuous inland Hill, or Object, fituated farther along the Coaft, the Pofition of which muft be determined afterward by another Bearing taken at a proper Diftance; and *that* Hill will then ferve for the fame Ufe between Station III. and IV. as the other Hill does between Station II. and III. Then take the Bearing of the Point, or Head, B, next you; eftimate its Diftance, and mark it on the Paper in the Bearing-line with a Dot, and N° II. for the fecond Station, or Beginning of the fecond Sketch; alfo the Bearing of a diftant Point or Promontory, for the other End of it; eftimate its Diftance by the Eye, draw it out from N° II, and mark it with a Dot and the capital Letter C. Then take Bearings of all the Heads, Points, Inlets, &c. between B and C, eftimate their Diftances, and mark them on the Bearings, and fketch the Figure of the Coaft between the Points, and proceed as was directed at Station I. till the whole is finifhed in the fame Manner. This however is but a rough imperfect Sketch, and muft be corrected at more Leifure, by drawing the whole anew on clean Paper from the Diftances and Obfervations in the Obfervation-Table.

10. If the Coaft lies northward and fouthward; obferve the Latitudes of the Heads, Points, or Inlets, at every 20 or 30 Miles Diftance, if it can be done; and by thefe let the principal Diftances be a fecond Time corrected. If the Coaft lies nearly Eaft and Weft, the Diftance cannot be corrected by Latitudes, and therefore frequent Obfervations of the Sun are unneceffary.

11. When you are obliged to leave off the Work for want of Day-light, or by bad Weather, do it as near fome Head, or remarkable Part of the Coaft as you can; take Bearings, or Marks, on the Place you left off at, that it may be eafily found when you want to begin again.

12. If the Coaft navigated is a *Strait*, or the Mouth of a River, where the Land on each Side can be feen; at each Station on one Side, take the Bearings of remarkable Heads, Points, Iflands, Hills, &c. on the oppofite Side, and let that be *one* Direction by which their Pofitions and Diftances are determined.

A Coaft fketched in the above Manner may contain many good Harbours or Bays, which are not to be perceived in failing along it. If there is an
Opportunity,

Opportunity, the Ship fhould go into fome of them, until a Delineation was made of them, and the Entrance founded in and out; which would render the Sketch of the Coaft of much more Service.

CHAP. IV.

Rocks and Shoals determined and defcribed. Tides and Soundings. Tides defcribed. Harbours defcribed. Copying and reducing Draughts. Neceffary Inftruments.

SECTION I.

How to determine the Diftance and Extent of Rocks, Sand-banks, and Shoals, lying off a Coaft that has been furveyed; and how to avoid them by the approximating Angle.

TO determine their Diftance; anchor a Veffel at one End of the Rock, Sand-bank, or Shoal; and in the Veffel, with *Hadley*'s Quadrant, take the Angles between three Objects on Shore, whofe Diftances from one another are known, and (by longim. Prob. Page 18.) find the Diftance of the Veffel from thefe Objects, which will give that End of the Rock or Shoal.

Or, anchor a Boat at one End of the Rock, or Shoal, and take the Angles on Shore from two Stations whofe Diftance is known, and (by longim. Prob. Page 10.) find the Diftance of the Boat.

To find the Extent of the Rock, Sand-bank or Shoal; if its Extent is fmall, it may be eftimated by the Eye fufficiently near: if large, the other Extremity muft be determined in the fame Manner, by the Angles taken on Shore; or rather, by one Angle taken on Shore, and that Direction interfected by a magnetic Bearing at the other End before determined.

When a Coaft has been firft carefully furveyed, the Diftance of Rocks, Shoals, and Sand-banks may be found with fufficient Exactnefs by two Bearings of fome diftinct Part of them taken on Shore with a good magnetic

Needle;

Needle ; provided the Stations are not at ſuch a Diſtance, or Poſition, from each other as to make too oblique an Interſection.

If the Shoal lies ſo far from the Coaſt eaſtward or weſtward that the Land cannot be ſeen at it ; in moderate Weather, anchor a Veſſel at the Shoal, and two Boats with their Sails looſe at a proper Diſtance and Poſition from each other, between the Shoal and Land, and ſo as the Boats may be ſeen from the Shoal, and the Land ſeen from the Boats.   Let an Obſerver in each Boat take the Angles between three known Objects on Land with *Hadley*'s Quadrant ; and another Obſerver in the Veſſel at the Shoal, take the Bearing of the two Boats as exactly as poſſible with a Compaſs.   By the firſt Angles the Diſtance of the Boats from the Land, and from each other, will be found ; and by the Bearings, the Diſtance of the Shoal from the Boats, and of Conſequence from the Land, will likewiſe be determined.

The Diſtance of the Shoal from any one of the Boats may likewiſe be meaſured by the Velocity of Sound, by appointing two or three Guns to be fired from the Veſſel when a Signal is made, as directed in Long. Oper. 3.

If Boats, or ſmall Veſſels, cannot anchor within Sight of the Land, and, at the ſame Time, be ſeen at the Shoal ; then ſail from the Shoal towards the Land with a leading Wind, meaſure the Ship's Run carefully with a Log-line, and when the Land is ſeen diſtinctly, there drop anchor ; and find your Diſtance from it by *Hadley*'s Quadrant ; and the Diſtance run from the Shoal, added to the Diſtance of the Land (and reduced to one Direction, if neceſſary) will give the Diſtance and Poſition of the Shoal from the Land nearly.   If the Shoal lies North or South from the Coaſt, its Diſtance may be found by the Latitude, and the Ship's Courſe in ſailing towards the Land.

At every Rock, Shoal and Sand-bank, Marks ought to be taken on the Land, for avoiding them.   In doing this, chuſe ſuch Objects only as are remarkable and ſtriking, which a ſtranger to the Coaſt may readily diſtinguiſh ; and not ſuch as are ſmall, or faint, which none but a Perſon particularly acquainted in the Place can find out.   If no ſuch diſtinct Land-marks can be found for directing Veſſels paſt them ; then they may be avoided by the *Approximating Angle*, taken in the following Manner.   On the Out-ſide of ſuch Rock or Shoal, with *Hadley*'s Sextant obſerve carefully the Angle which two

<div align="right">remarkable</div>

remarkable Objects on the Land, at a proper Diftance and Situation, fub-
tend; take alfo their Bearings by the Compafs; and write all down for future
Ufe. And while at any other Time, in failing towards that Shoal, the Angle
between thefe two Objects is found *lefs* than the approximating Angle, you
are certainly without the Shoal; and alfo without all Rocks or Shoals lying
within a Circle that may be fuppofed to pafs through the two Objects on
Land, and the Point where the approximating Angle was taken. For all
Angles *in* the Periphery of that Circle, which the two Objects fubtend, are
equal; the Angles *within* the Periphery, greater than thefe; and the Angles
without it, lefs. Euc. iii. 21. The Bearings will fhew when you are a mo-
derate Diftance from it on either Side.

To find out Shoals that may be along any Coaft : in blowing Weather, go to
the Top of a Hill, Cliff, or Eminence, and obferve where the Sea appears
rougher, or the Waves break more, than in other Parts, for there the Water
is fhalloweft; except the Roughnefs arifes from a Stream of Tide going
againft the Wind; or two Streams meeting each other. Take Land-marks,
or the Bearing of the Breakers, from one, or two, remarkable Places, and
that will direct you to the Shoal in a Boat afterwards, when the Weather is
moderate.

Or, in a Calm, obferve juft after Slack-water, where a grey Stream, or
Ripple on the Surface, firft begins; and at the fmooth Edge of that Ripple
the fhalloweft Water will be found.

Breakers are often feen in calm Weather, before a Gale of Wind, where
the Water is fhallower than in the neighbouring Parts; though there may
be a fufficient Depth where the Breakers rife.

SECTION II.

Circumftances to be taken Notice of in defcribing Rocks, Shoals and Sand-banks.

It may not be unneceffary firft to caution a Surveyor againft taking his
Accounts of Rocks, Shoals, Tides, or Harbours, folely from the Informa-
tion of others, without examining them himfelf : for there are few to be met
with who have been careful and circumftantial enough in their Obfervations;

and

and fome who will affirm for Fact, as if grounded on actual Obfervation, what is only a vague Opinion long entertained on uncertain Authority. Even profeffed Pilots are often fatisfied with knowing how to avoid Dangers by keeping at a fufficient Diftance from them, or in the common Channel, without troubling themfelves about farther Particulars. Information fhould be made Ufe of, but only as a Direction for farther Inquiry, and to facilitate your own Search and Examination. In defcribing Rocks, Banks, and Shoals,

1. Take Notice how far they lie from fome remarkable Head, or Part, of the neareft Land; and how they bear from that and from fome other confpicuous Part of the Coaft.

2. How far they extend in Length, and in what Direction.

3. What Land-marks lead directly on them.

4. At what Time of the Tide they begin to dry, or are covered.

5. The leaft Water on the Shoal.

6. How they are to be avoided on each Side.

7. The approximating Angle, if diftinct Land-marks are not to be found.

SECTION III.

Affections of Tides relative to the Soundings.

As the perpendicular Rife of fpring and neap Tides varies fenfibly according to the Diftance and Pofition of the Moon with Refpect to the Earth; and of the Earth and Moon with Refpect to the Sun, and alfo by Winds and Weather; the Depths of the Water proper to be inferted in Draughts of the Sea-coaft, feem to be fuch only as are taken at low Water in ordinary Spring-tides; and not fuch as are found when the Tides are affected by extraordinary Caufes. Ordinary Spring-tides may be reckoned, fuch as happen in moderate Weather, on the third Day after new or full Moon, when fhe is at her mean Diftance from the Earth, and the Sun not near the Equinoxes.

O   It

It would be extremely tedious to wait for low Water Spring-tide, to take all the neceffary Soundings. Therefore, that the Depths proper to be marked may be known, whatever Time they are taken, let the perpendicular Rife, or Fall, of the Water, in moderate Weather, on the third, or fourth Day, after Full or Change, and after Quarter Moon, be firft found by Experiment; and then the Depth at low Water ordinary Spring-tide may be known fufficiently near, by making the following Allowances at the Time each Depth is taken.

If the Depth is taken at High-water Spring-tide, then deduct the full Rife of ordinary Spring-tide from the Depth found, and the Remainder will be the Depth to be inferted in the Draught.

$$\text{Spring-tide, at the}\begin{cases} \text{1ft Hour before and after High-water, deduct } \frac{11}{12} \\ \text{2d Hour before and after High-water, deduct } \frac{3}{4} \\ \text{3d Hour before and after High-water, deduct } \frac{1}{2} \\ \text{4th Hour before and after High-water, deduct } \frac{1}{4} \\ \text{5th Hour before and after High-water, deduct } \frac{1}{12} \\ \text{6th Hour, or about Low-water, deduct } \quad 0 \end{cases}\begin{array}{l}\text{of the full} \\ \text{Rife of or-} \\ \text{dinary} \\ \text{Spring-tide.}\end{array}$$

If the Depth is taken at High-water Neap-tide, from each Depth deduct ⅘ths of the full Rife of Spring-tide, or the whole Rife except one fifth Part.

$$\text{Neap-tide, at the}\begin{cases} \text{1ft Hour before and after High-water, deduct } \frac{4}{5} \\ \text{2d Hour before and after High-water, deduct } \frac{3}{4} \\ \text{3d Hour before and after High-water, deduct } \frac{1}{2} \\ \text{4th Hour before and after High-water, deduct } \frac{1}{4} \\ \text{5th Hour before and after High-water, deduct } \frac{1}{5} \\ \text{6th Hour, or about Low-water, deduct } \quad \frac{1}{3} \end{cases}\begin{array}{l}\text{of the full} \\ \text{Rife of} \\ \text{Spring-tide.}\end{array}$$

Thefe Allowances are not given as quite precife, for they will vary a little from feveral Caufes; but as a general Rule, which will be found fufficiently exact on moft Occafions. Shoals and Channels that have lefs than four Fathoms, and are much in the Way of Shipping, require to be founded at low Water Spring-tide, that the Depth of the Water there may be more precife.

That the Depths to be marked may be known with more Exactnefs, let it be obferved, that when the Moon is in the Perigea, or leaft Diftance from the Earth, then the perpendicular Rife of fpring and neap Tides are about

one

one eighth more than ordinary; and that about the Equinoxes, the full Rife is about one tenth more, from that Caufe alfo: that when the Moon is in the Apogea, or at her greateft Diftance from the Earth, then the Tides are proportionally lefs than ordinary: fo that fometimes the greateft neap Tides may rife as high as the leaft fpring Tides. But thefe and other Affections of the Tides have not yet been fo minutely inquired into as they deferve. Hard Gales of Wind in any Place, efpecially if it blows in the Direction of the Flood, fwells the Tide to an uncommon Height: Storms at a Diftance, are found fometimes to occafion an extraordinary Rife of the Water in Places where the Gale is not felt: and two Streams of Tide running round an Ifland, make the Tide rife higher near their Meeting than it does in other neighbouring Parts.

Where the Depth at low Water is above five Fathoms, there a Foot or two, more or lefs, is of no great Confequence; and therefore it is fufficient if the Deduction from the Rife of fpring Tide is in Proportion to the Time of the Tide: that is, at high Water, deduct the full Rife; at quarter Ebb, three Quarters; at half Ebb, or Flood, half the Rife; and at three Quarters Ebb, or one Quarter Flood, deduct one Quarter of the full Rife from each Depth found.

The beft Way to find the exact Time of high Water on the full and change Days is, in moderate Weather, when the Sea is fmooth; then, about three Hours before high Water, mark the Place on the Shore to which the Tide reaches, and write down the Hour and Minute you obferved it: on the Ebb, watch till the Tide falls to the fame Mark on the Shore, and fee what Hour and Minute it is then; and to the Time between the two Obfervations add two Minutes for each Hour, on Account of the Acceleration of the Tide, and half that Sum, added to the Time of the firft Obfervation, will be the true Time of high Water that Day.

S E C T I O N   IV.

Circumftances to be taken Notice of in defcribing Tides.

1. Obferve the Time of high water on the full or change Day of the Moon. Let it be expreffed in Hours and Minutes, not as is commonly

done

done, by the Bearing of the Moon, which ferves no ufeful Purpofe what-ever, but always occafions an unneceffary Reduction of Time, and Points of the Compafs, into one another.

2. Obferve the perpendicular Rife of the Tide on the third, or fourth Day, after new or full Moon; and at different Seafons of the Year; and when the Moon is in the Perigea and Apogea.

3. Obferve the Direction of the Streams of Flood and Ebb, near the Coaft, and at a Diftance from it; the Irregularities, or Variations of their Direction; and at what Time of the Tide on the Shore, the Stream in the Offing begins to turn.

4. Obferve the greateft Velocity of the Stream at fpring and neap Tides, off the Coaft, and in Channels; meafured by a Log-line heaved from a Boat or Ship at Anchor; or by driving with the Stream, in a Calm, a known Diftance.

5. In fpeaking of irregular Tides, do not fay, it flows 9, or 8 Hours, and ebbs 3, or 4 (as is often done) when you mean only, that the Stream runs 9, or 8 Hours one Way, and 3, or 4 the other; for that creates Con-fufion, and fometimes Miftakes. While the Tide rifes, and then only, it is Flood; and only while it falls, is it Ebb; in whatever Direction thefe Streams run. Therefore always exprefs fuch an Irregularity in the Stream, by the Time it *runs* in one Direction, and the Time in the other.

SECTION V.

Circumftances to be taken Notice of in defcribing Harbours.

1. Obferve if they are well fheltered, or, on what Quarter they are expofed.

2. The Depth of the Water, and Nature of the Ground in the Anchorage.

3. What Number of Ships they are capable of containing eafily; and of what Size, or Draught of Water.

4. In what Part to anchor; and the Land-marks, or Bearings for it.

3

5. How the Entry may be diftinguifhed at a Diftance, or how to fall in with it coming from Sea.

6. How to avoid Rocks and Shoals in the Way to a Harbour; or failing to the Anchorage.

7. If there is a Sufficiency of frefh Water, and where it is; and what Provifions the Place affords.

8. In unknown Places, obferve what Forts, or Batteries are in them; what their Strength is; and how near a large Ship may get to them : or, in what Parts of the Harbour, Forts, or Batteries, may be advantageoufly erected, either for Defence, or Attack.

SECTION VI.

How to copy a Draught exactly.

Pin clean Paper over the Draught to be copied, fo as they may not fhift: hang, or hold, them up before a Window, or the Glafs of a Chariot, and the Drawing will appear through the clean Paper, and may be traced on it with a black-lead Pencil, and afterwards with Ink.

Or, rub the Back of the Draught, or as much of it as may be neceffary, over with Charcoal; lay the rubbed Side on clean Paper, and pin them toge-ther, and lay both on a Table, the Draught uppermoft, and with a fmooth-pointed Tracer, of Brafs, Ivory or Steel, not very fharp, trace exactly all the Coaft-line firft, and then other Parts, and the Under-paper will retain the Impreffion diftinctly. If the Charcoal ftains other Parts of the Under-paper, it will rub out by the Crumb of Loaf-bread, after the Tracing is inked.

If, in the Copy, you want the true Meridian right up and down on the Paper, inftead of the Magnetic : draw the true Meridian firft on the Middle of the original Draught; then in a proper Part of the clean Paper (before it is pinned to the other) draw a Line right up and down; and pin them together fo, that the Line on the clean Sheet may lie exactly under, or

over.

over (according to the Manner of copying) the true Meridian drawn on the Original; then trace the one from the other.

SECTION VII.

How to reduce a Draught to a smaller Scale.

A Pantagraph is by far the easiest and most expeditious Instrument for diminishing Draughts with Accuracy : but, when one of a sufficient Size for large Draughts cannot be got, either of the following Methods will serve.

With Black-lead draw the large Draught all over with Cross-lines, forming exact Squares : draw the clean Paper for the Copy also over with the same Number of Squares; but their Sides smaller, in Proportion to the intended Size of the Scale; such as one half, one fourth, &c. of the Length of the other : distinguish, by a stronger Line, and mark with a Figure, every fifth or sixth Row of Squares in both, so that the several corresponding Squares may be more readily perceived : then, in each of the small Squares, draw, by the Eye, a Curve similar to that which is in the corresponding larger Square, till the whole is copied.

Or; draw a Black-lead Line from End to End of the large Draught, in any Direction, as A B (Plate III. Fig 7.) by its proper Scale divide that Line into any Number of Miles, or half Miles; at each Division raise Perpendiculars, and draw them out to the Coast-line, and mark them 1, 2, 3, &c. at each End.

On a proper Part of the Paper for the small Draught, draw a Black-lead Line right up and down on the Paper, for the Meridian; and another Line making the same Angle with it, as the divided Line in the large Draught does with its Meridian, and in the same Position as a b (Fig. 8.) make a b the half, the fourth, &c. of A B, according to the intended Diminution of the Scale; divide it into the same Number of Miles, or half Miles, by its proper Scale, as the other is; at each Division raise Perpendiculars, draw them out a sufficient Length, and mark them at each End, 1, 2, 3, &c. as in the other, that the corresponding Perpendiculars may be readily found.

<div align="right">Measure</div>

Measure on its proper Scale the Length of the first Perpendicular on A B, in Miles and Parts of a Mile: take the same Number of Miles and Parts from the small Scale, and set it from 1 to 1, in the small Figure, and mark it with a Dot: do the same in every other Perpendicular, and so many Points of the Coast in the small Figure will be found.

Then, between every two extreme Dots in the small Figure, sketch by the Eye the corresponding Curve of the large Coast, and both Figures will be similar in every Respect. Hills, Rocks and other Objects may be drawn in the same Manner.

There are proportional Compasses and Compasses with three Legs made, by which small Draughts may be diminished; but they do not answer so conveniently for very large Draughts.

SECTION VIII.

Instruments and other Necessaries for taking a Survey of the Sea-coast.

A good astronomical Quadrant 14 Inches Radius of *Bird*'s Construction; with a Pirn of fine Silver-wire for the Plummet.

A *Hadley*'s Octant, 18 Inches Radius.

A *Hadley*'s Sextant of Brass, 9 Inches Radius.

A Bell-metal Theodolite, with a spirit Level, Needle and two Telescopes: the Objects to be seen direct through the Telescope, not inverted.

A Case of good Pocket-instruments.

A Brass-scale 3 Feet long, with various Lines of equal Parts on it.

A Wooden-ruler 5 Feet long.

A beam-compass of Wood two Feet long and ¾ broad, divided from the Center Point along a chamfered Edge into Inches and eights of an Inch.

A *Gunter*'s Scale 2 Feet long; and one a Foot long.

A Brass

A Brafs circular Protractor 12 Inches Diameter, with an Index and Pricker to mark the Degrees and Minutes on the Paper; the graduated Edge filvered. Another 5 Inches Diameter; and another femicircular, 3 Inches Diameter.

A meafuring Pole 30 Feet long, divided into Feet; and confifting of two Pieces that may be joined together End-ways, and taken afunder at Pleafure.

A ftraight Mahogany-pole, precifely 6 Feet long, divided into Feet and Inches; the two extreme Feet into Decimals of an Inch.

Two Iron-chains, each 60 Feet long; each Link a Foot, and the Thicknefs of a Quill; with brafs Marks at every tenth Link.

Four Iron-Reels, with Stakes and Lines, fuch as Gardeners ufe.

Three wooden Poles, each 10 Feet long, and $1\frac{2}{3}$ Inches Diameter; 12 Poles, each 6 Feet long and one Inch Diameter: all pointed with Iron on a Socket, fo as to pierce the Ground eafily and ftand firm in it.

Thirty cylindrical Iron-pins, fharpened at one End, for piercing the Ground at the End of each Chain, or Meafuring-pole; each about 8 Inches long and half an Inch Diameter.

Two Canvafs-pockets for holding thefe Pins, with Strings for tying them round the Wafte of the Meafurers.

A good amplitude Compafs.

A magnetic Needle, with an agat Cape, Brafs graduated Circle, and a Lever, in a fquare wooden Box, with jointed Sights to lie within the Box when fhut.

A Pocket-compafs, with an agat Cape.

A Ship's-compafs, for taking Bearings in the Boat; the Depth of the Box equal to the Diameter of the Card, fo as not to touch the Glafs above, nor the Bottom below with any Motion; and the Angle of the Cape a Right-angle.

A good portable refracting Telefcope, of *Doland*'s Conftruction.

A Cafe

A Cafe of Leather, divided Length-ways by Pafteboard into two Apartments, 2 Feet 1 Inch long, and 18 Inches broad; for holding the original Draught, fpare Paper, Scales and Protractors, and fecuring them from Rain and Salt-water: alfo a fmall Drawing-broad, the Size of the Cafe, with Leather Straps and Buckles, for carrying both together over a Man's Shoulder.

A Draught-cover, 2 Feet long, and 18 Inches broad, made of Pafteboard covered with Oil-cloth, like the Cover of a Book, for laying the original Draught in, that it may flip eafily in and out of the Leather Cafe without Injury.

A good Stop-watch, that fhews Seconds.

A Two-foot reflecting Telefcope, for obferving Eclipfes of Jupiter's Satellites, or of the Moon, when neceffary to find the Longitude.

A large Drawing-table, 7 Feet long, and 5 Feet broad, with a round Moulding along the Edge of one Side and one End, to keep the Paper fmooth when drawn over the Table to reach the Top of the Draught. The Board, when not in Ufe, to come afunder in two Leaves, one of the Leaves $1\frac{1}{2}$ Inch broader than the other: when in Ufe, to be faftened together on the under Side by two Hooks, one near each End; and to be fupported by a Frame, or by a long three-legged Stool at each End; with a loofe Poft, or Pillar, under that Side where the Drawer commonly fits, that the Board may not warp, or bend, by his Weight when leaning on it: the Parts of the Frame, or Stools, to be made and marked fo as to be eafily taken to Pieces, or joined, occafionally.

A Folio Obfervation-book of 4 Quires medium Paper, ruled at the Top for a running Title; and for a local Title; a two-inch Margin on the left Side of each Page; and and two Columns on the Right: the firft half an Inch, for Degrees and Minutes, the other one Inch, for magnetic Bearings.

A Folio Journal-book, of 3 Quires medium Paper, ruled at the Top; with a two-inch Margin, and a fmall Column for the Days of the Month on the left Side of each Page.

P   A View

A View-book, of half a Quire imperial Paper, opening Length-ways to the Extent of two Sheets, and twelve Inches broad; the Leaves pasted and guarded in the Middle.

Memorandum-books, each of 6 Sheets Demy-paper, with red Leather Covers.

East India, or such other large Paper, for the original Draughts; that may bear to be often folded without cutting.

Imperial Paper for the Draughts.

Transparent Paper, for copying Parts of a Draught readily for occasional Service.

Writing Paper.

Cartridge Paper, for covering up a clean Draught while it is making out.

Quills, Crow-quills; Cake-ink, Indian-ink; Hair-pencils, some of the smallest, and some of a middling Size; Black-lead Pencils, some of which flat; Charcoal, for copying a Draught by tracing it on a Table; Penknives.

A Survey-boat, or six-oar'd Cutter, 24 Feet from Stem to Stern, 7 Feet 3 Inches broad, and 2 Feet 11 Inches deep, with Wash-boards, Masts, Sails, &c. and two Graplings, a larger and a less; the larger to have a Block made fast to the Ring for running 40 or 50 Fathoms of Rope through, in order to moor the Cutter off the Shore or Rocks, and haul her in or out at Pleasure. Also an Awning of painted Canvas to sleep under where it is not safe landing. Such a Boat will carry, of King's Allowance, one Week's Beer, and two Weeks Provisions (Water and Firing excpted) of all other Kinds for eight Persons; together with a Tent, Bed-cloths and cooking Vessels; and is fit for rowing as well as sailing, if made light.

A Captain's Tent and Marki, with a Bed and Bedding to serve two Persons.

A Vessel about 120 Tons Burden, pretty broad in the Beam, and full in the Bows; and of such a Mould as to draw little Water, and to take the Ground easily;

eafily; with a Cabbin 12 Feet in the Floor, well lighted, and fit to hold the above-mentioned Drawing-table. Her Complement of Men (befides the Surveyor, his Affiftant and two Servants) to be a Mafter, a Purfer, a Mate, a Midfhipman, a Carpenter, a Sail-maker, a Boatfwain, a Cook, fourteen able Seamen before the Maft, and a Pilot for the Coaft. A larger Veffel cannot go into fmall Creeks, which will often retard the Service, and be found very inconvenient on a Survey: a Veffel much lefs, cannot keep Sea well, nor carry Provifions and other Stores fufficient for the Seafon; which is likewife a Difadvantage. In hot fickly Climates, and Countries where Seamen cannot be got eafily, a greater Number of Hands will be neceffary, and likewife a Surgeon. If the Surveyor has two Affiftants under his Direction, that both may be employed at the fame Time, another fix-oar'd Cutter, with fix Hands more, will be neceffary: and, if the Coaft has many Shoals, Sand-banks, or Bar-harbours along it, or few Harbours that are acceffible at all Times of the Tide, a Pilot for each Boat, who is minutely acquainted with the Coaft, will alfo be neceffary, to guard againft Misfortunes, and for finding out the Shoals and Channels more readily.

C H A P. V.

Sec. 1. To find the Longitude by an Eclipfe of one of Jupiter's Satellites. 2. To continue a Meridian through a Kingdom. 3. To trace a Parallel of Latitude through a Kingdom.

SECTION I.

How to obferve an Eclipfe of Jupiter's Satellites, in order to find the Longitude of the Place of Obfervation.

THE moft exact Survey of a Coaft cannot be reckoned complete, till its Longitude from fome other noted Place is known: and the moft careful Surveys, if they extend far eaftward, or weftward, will require to be corrected by an Obfervation of the Longitude. It is therefore a neceffary Part of a Surveyor's Bufinefs to underftand how this Problem is to be performed.

For

For determining the Longitude of one Place from another on Land, Eclipses of Jupiter's Satellites, especially of the first, are found to be the most advantageous celestial Appearance. If the Hour, Minute and Second when any such Eclipse happens is observed in two Places, the Difference of these Times, converted into Degrees, Minutes and Seconds of a Circle, will give the Distance of their Meridians, or the Longitude of one Place from the other. Or, if the precise Time of an Immersion, or Emersion at one Place is known by Calculation, and found by Observation at any other, their Difference of Longitude will then be known. There are Tables published annually, in the nautical Almanack, of the Time at Greenwich, when Jupiter's Satellites will be eclipsed: if therefore the Time in another Place, when such Eclipse happens, especially of the first Satellite, is found by Observation, their Difference of Longitude will be then known.

To find the precise Time of the Day at which an Immersion, or Emersion of a Satellite is observed, four principal Operations are necessary. 1. *To find an exact Meridian-line*, so that by it a Clock, or Watch, may be set either to apparent or to mean Time at the Place of Observation. 2. *To regulate the Clock or Watch*, so as they may keep equal Time: or, to find the Error of their Going, that proper Allowance may be made for it. 3. *To set the Clock, or Watch, to mean or equal Time by the Meridian-line*. 4. *To observe, and note, the precise Moment when the Eclipse begins, or ends.*

1. *To find an exact Meridian Line.* For doing this, see several Ways by the Stars (Part 1. Beginning at Page 47.) which are more to be depended on than any Observations of the Sun, if the Observer is not provided with the best Instruments and a convenient Observatory.

2. *To regulate a Clock, or Watch, so that they may keep equal Time*; or to find how much they go fast or slow, that Allowance may be made for it. The most simple and certain Test of equal Time is, the diurnal Rotation of the Earth on its Axis: or, which results from it, the apparent daily Revolution of the fixt Stars round the Axis of the Earth. By that, therefore, let your Clock, or Watch, be regulated, as directed in Merid. Prob. Page 56.

3. When

3. When the Clock, or Watch, is regulated to go equally, or the Error of their Going is found; *then let them be set to the mean Time * of the Day by the Meridian-line*, in the following Manner.

In a Room with a large Door, Window, or Opening towards the North, from whence your Meridian-line northward may be seen (if the Meridian has been marked toward the North) and another Door, Window, or Opening, towards the South, right opposite to the other, through which the Sun may be seen at Mid-day; hang up two Plumb-lines exactly in the Meridian, as far asunder as conveniently may be; let the Plummets, or Weights, be as heavy as the Lines will easily bear; and make them swing in Water, to prevent shaking by the Motion of the Air. Stop the Clock, or Watch, precisely so many Minutes and Seconds before, or after twelve, as are equal to the Sun's Equation that Day, which may be found in Equation Tables; and with a smoked or tinged Glass before your Eye, observe when the Center of the Sun comes exactly in a Line with the two Plumb-lines, and that Moment call out, *Now*; that your Assistant may set the Clock, or Watch, agoing immediately. Or, which perhaps is more accurate, stop the Clock as many Minutes and Seconds before the Time pointed out by the Equation, as the Center of the Sun takes to move the Length of his Semi-diameter that Day (which may be found in the nautical Almanack) and when the western Edge of the Sun just touches the Plumb-line, set the Clock, or Watch, agoing, and they will then be set to mean or true Time. In most Places it will be necessary to have a small temporary Room, for an Observatory, built on purpose; with an Opening toward the North, and another toward the South, that may be shut at Pleasure, to keep out any Draught of Air which would disturb the Plumb-lines.

* Mean, or equal Time is, the Time shewn by a Clock that is set right, and goes exactly equal. Or, it is the Time shewn by the Sun, corrected by the Equation; or when Allowance is made for the Inequality of the Sun's Motion.

Apparent Time is, the Time shewn by the Sun (whether in the Meridian or not) without making any Allowance for the Inequality of the Sun's Motion: this is the Time shewn by a good Sun-dial; or found by an Azimuth or Amplitude of the Sun.

Equation of Time is, the Acceleration, or Retardation, of the Sun's Motion; or how much the Sun is too fast, or too slow, of equal Time.

4. To

· 4. *To obferve, and note, the precife Time of the Immerfion, or Emerfion, of a Satellite :* Two or three Days preceding the Night of the Eclipfe, fet your Clock, or Watch, to mean Time by the Sun and the Meridian; and, if it can be done, examine its Accuracy, the Day of the Eclipfe alfo ; but without altering the Clock, though it has not gone quite exact ; for Clocks and Watches often go irregular a little after they have been fet back or forward : only, note how much it is lefs, or more than the mean Time each Day, that proper Allowance may be made in fettling the true Time of the Eclipfe. Guefs as near as you can to your Longitude from Greenwich, and from thence find at what Time the Eclipfe may be expected with you : if you are eaftward of Greenwich, the nominal Time it will happen with you will be fo much later than at Greenwich ; if you are weftward of Greenwich, the Time with you will be fo much fooner, according to the Longitude. An Hour before it is expected, adjuft the Telefcope * to your Sight, fo as to fee Jupiter's Belts diftinctly. A Quarter of an Hour before the Eclipfe is expected (or more, if your Longitude is very uncertain, or if it is any Satellite but the firft) fit down to your Telefcope ; and if it is an Emerfion, keep looking towards that Part of Jupiter's Difk on which you find, by the nautical Almanack, it is to happen. But obferve, that if your Telefcope inverts Objects, the Eclipfe will happen on that Part of Jupiter's Difk which is diametrically oppofite to that in the Almanack. While you are watching the Appearance of the Satellite, let your Affiftant count every Second audibly, by the Beats of the Clock, or by the Motion of the Second-hand of the Watch ; and the Inftant the Satellite appears, if an Emerfion ; or the Inftant it difappears, if an Immerfion, call out, *Stop :* and immediately, the Affiftant fhould repeat the laft Second he counted, which the Obferver fhould note down directly, while the Affiftant looks to the Minute, and notes it down. Write down likewife what Sort of Telefcope you obferved with, and its length and magnifying Power : for Eclipfes will be perceived fomewhat fooner by a good Telefcope than by one of a worfe kind.

* The Telefcopes proper for obferving the Eclipfes 'of Jupiter's Satellites are, common refracting Telefcopes, from 15 to 20 Feet ; reflecting Telefcopes of 18 Inches or two Feet ; and Telefcopes of Mr. *Dollona*'s Conftruction, with two Object-glaffes, from 5 to 10 Feet : or, which are ftill more convenient, thofe of $3\frac{1}{2}$ Feet, which he has conftructed with three Objectglaffes.

An

An experienced Obferver may count the Seconds by the Beats of the Clock, without an Affiftant; but one unaccuftomed to thefe Obfervations, by attending to the Time and Satellite together, will be liable to a Miftake in one, or to Inaccuracy in the other.

If it is the apparent Time of an Immerfion, or Emerfion, that is obferved, (which is found by fetting the Clock to Twelve, when the Sun's Center is on the Meridian) it muft be corrected by the Equation anfwering to the Time of the obferved Eclipfe, to reduce it to mean Time, to which Eclipfes are calculated in the Almanack; and the Difference between the calculated Time at Greenwich and the equated obferved Time of the Eclipfe, converted into Degrees and Minutes, will be the Longitude from Greenwich. To convert Time into Degrees and Minutes of a Circle: for every Hour allow 15 Degrees; for every Minute of Time over the Hours, 15 Minutes of a Degree; and for every Second of Time over the Minutes, 15 Seconds of a Degree.

Emerfions are vifible only from the Time of Jupiter's Oppofition to the Sun, to the Time of his Conjunction: during which Time, he rifes after the Sun fets. Immerfions are vifible only from his Conjunction to his Oppofition; during which Time, he rifes before the Sun fets.

To find when Jupiter is above the Horizon, and to diftinguifh him amongft the Stars; the eafieft and readieft Way is by a celeftial Globe, as follows. Find his Place in the Ecliptic from an Ephemeris for the Day propofed; alfo his Latitude, or Diftance South or North of the Ecliptic; mark that Diftance on the Globe on a Circle of celeftial Latitude paffing through his Place in the Ecliptic. Rectify the Globe for the Latitude of the Place yon are in, and for the Sun's Place at Noon, and fet the Hour Index to 12; turn the Globe till the Hour Index points out the Hour propofed; lay a Quadrant of Altitude from the Zenith over the Point marked on the Globe for his Place, and it will fhew his Height above the Horizon, and likewife his Azimuth at that Hour: allow for the Variation of the magnetic Needle, and you will have his Bearing by the Compafs. By the Altitude and Bearing Jupiter will be eafily found among the Stars, for he is the largeft to Appearance of the Stars and Planets, except Venus, who is likewife a little brighter than he.

Though

Though an Eclipse of Jupiter's first Satellite is much more to be relied on than the rest, because the Irregularities of its Motion are better known; yet Eclipses of the other Satellites ought not to be neglected when there is an Opportunity of observing them: because such Eclipses may be observed in some other Place; by which the Difference of Longitude of these two Places will be as exactly known as by an Eclipse of the first Satellite; and if the Observations and Telescopes are good, is more to be depended on than any Calculation.

If the Part of Jupiter's Disk, and the Distance from it, at which the Emersion of a Satellite will happen, are known, that seems preferable to an Immersion; because the Appearance of any luminous body is more instantaneous than its Disappearance.

To find the Longitude of a Place by an Eclipse of the Moon; a Meridian Line must be first found; then a Clock, or Watch, regulated to keep equal Time, then set to mean or true Time by the Sun in the Meridian, as before directed. Then the precise Time noted by a Clock, or Watch, when the Moon's eastern Limb touches the Earth's Shadow; also the Time when the Shadow touches some remarkable Spots in the Moon's Disc; and when the Moon's western Edge touches the Shadow at its going off, when the Eclipse is just over: these several Times, compared with corresponding Observations in other Places, or with a Calculation, will give the Longitude between these Places. But Eclipses of the Moon are not to be relied on nearer than to three or four Minutes of Time; chiefly from the Difficulty of distinguishing the Edge of the Shadow precisely: and therefore Eclipses of Jupiter's Satellites are to be preferred to lunar Eclipses, for determining the Longitude of any Place.

SECTION II.

How to continue a Meridian Line through a Kingdom, or large Country.

PLATE III. FIG. IX.

First chuse some remarkable Place from whence to begin the Meridian, as a noted Observatory, Church, Castle, Hill, &c: if it is near the Middle of

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the Kingdom, fo that the Meridian may be continued northward and fouth-ward from it, it is the better.   Then provide a fkilful and faithful Affiftant, with two Sets of Inftruments, one Set for yourfelf, and one for him; and fix Men, at leaft, to attend each.   Provide alfo two convenient Tents, one for lodging you, and your Attendants and Inftruments, the other for him, his Attendants and Inftruments.   The Tents will ferve likewife for Signals, and for making Obfervations in, and fhould therefore be fo contrived, that a Breadth, or two, of the Cloth at each End, from Top to Bottom, may be laid open occafionally for obferving the Stars.   The neceffary Inftruments are, two Sextants of two Feet Radius, graduated fo as to be capable of taking horizontal Angles to Parts of a Minute; with a fpirit Level, and two good Telefcopes to each, with Crofs-wires in the common Focus of the Glaffes, and a fteady Stand to fupport the Inftruments horizontally: two good mag-netic Needles with Sights; four Plumb-lines, each fix Feet long, and two Stands for them, one to fupport two together, about four Feet afunder; fix ftraight fpiked Poles, each twenty Feet long, with black and white Flags for their Tops, to render them confpicuous, as they happen to bear on the Sky, or on dark Land; and a Line drawn on one fquare Side of each, right up and down, for a Plumb-line to be applied to, in order to fet them per-pendicular: if the Plumb-line is hung in a Box, to fcreen it from the Wind when applied, it would be an Advantage.   A Borer, or fome fuch Inftru-ment, for readily making a Hole in hard Ground for the Poles to ftand in firmly: in Wind, thefe Poles will need to be fupported by Ropes from the Top, like a Tent-pole, or by three fpreading Legs like a Theodolite: twenty fpiked Poles, each fix Feet long; a meafuring Pole, or Chain, with Reels and Lines on them, for meafuring a ftraight Line on the Ground.

At the Place where the Meridian is to begin, find an exact Meridian Line, by one of the moft accurate Methods explained in Part 1. (beginning Page 47.) mark its Extremity by a long Pole fet perpendicular in the Ground, and a Flag at Top.   Continue the Direction of that Part of the Meridian farther, if neceffary, by taking that Pole, and the Pole or Object you be-gan at in a Line; or by fetting other upright Poles in the fame Direction, till you come to the Summit of a Hill, or Eminence, where there is an ex-tenfive View beyond it; there mark a Point in the continued Meridian, by a Pin driven in the Ground, and pitch your Tent over it, fo that the two

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Tent-

Tent-poles may ftand parallel to the Meridian, at about the Diftance of a Foot from it, and not hinder your feeing any Objects that are in the Continuation of it. Within the Tent (that your Obfervation may not be difturbed by the Wind) hang two Plumb-lines on their Stand; and when at Reft, make them hang exactly in the Meridian backward, or toward the Beginning of the Meridian, by cutting the Object you began at, and one or more of the Poles which continued the Meridian. Stand next behind the other Plumb-line, and, when both are at Reft, obferve if they cut any fmall remarkable Part of a diftant Object which may be precifely known when you go to the Object; if fo, then is that Part of the Object in the Meridian; which may be continued from it as before, by taking it and the Middle of the Tent in a Line, till you come to fome neighbouring Hill, or Eminence, convenient for pitching the Tent on, and making Obfervations. But if the Plumb-lines do not cut fuch a fmall diftinguifhable Part of an Object (which indeed will very feldom happen) then proceed in the following Manner.

Find out fome Hill, or Eminence, on one Side of the Direction of the Plumb-lines (the nearer to it the better) and fo far off as that your Affiftant, at that Eminence, may fee your Tent, and you may fee his, when it is pitched on it: if they can juft be perceived by the naked Eye, it is fufficient; for then they will be diftinctly feen through the Telefcopes on the Sextants. Let your Affiftant take the Bearing of the Hill, and of the Direction of the Plumb-lines with the magnetic Needle, and note them down, and thefe will ferve to direct him nearly to the Hill and Meridian: fend your Affiftant to the Hill propofed, with his Tent, Servants and Inftruments, and let him pitch his Tent on a convenient Part of the Hill, or the neighbourhood of it, where he can fee your Tent, and you his; and, at the Door of his Tent, fet up a long Pole, with a confpicuous Flag at the Top of it, for a Signal to be obferved through your Telefcope: fet you up fuch another Signal in the Direction of the Meridian, near the Door of your Tent, to be obferved by him. As foon as his Signal is up, fet your Sextant level, with the Center of it at the Place of the Signal, and take the Angle which his Signal makes with the Meridian, or Direction of the Plumb-lines: write it down, and fend a Man with it to the Affiftant; when you have

done,

done, set up your Signal in its Place, with another Flag above the former, to signify that you have finished your Observation; and let them remain so till your Assistant's Tent is taken down.

When the Assistant has set up his Signal, then he must go as near the Direction of the Meridian as he can, by its magnetic Bearing which was taken at the Principal's Tent, and, in that Neighbourhood, find out some Eminence, or convenient Place, for the next Station, where his own Tent and the Principal's can be seen: there let him set up a large Pole and Flag, and two, or more, smaller, in a straight Line between it and the Signal at his Tent. Then, at his Tent-signal, let him take the Angle with the Sextant, formed by the Line of Poles crossing the Meridian and the Direction of the Principal's Signal, and write that down. This Angle, and that sent by the Principal, added together, and subtracted from 180° will leave the third Angle of the Triangle. Let him keep in the Direction of the Line of Poles, till he finds by the magnetic Bearing that he is in, or near the Meridian; then let him set up the Sextant, and observe the Angle between the two Tent-signals; if it is equal to the forementioned Remainder, the Center of the Sextant is in the continued Meridian: if the Angle observed is greater than that Remainder, the continued Meridian is farther from the Assistant's Tent than the Center of the Instrument; if the observed Angle is less, the Continuation of the Meridian is between the Instrument and the Assistant's Tent, and the Sextant must be shifted either one Way or the other, but always in the Direction of the Line of Poles, till this observed Angle, and the two formerly observed at the Tents, make exactly two Right-angles; then the Point directly below the Center of the Sextant is to be marked by a Pin driven into the Ground, and that will be another Point in the Meridian continued from the first Station. If this Place is not convenient for a new Station, he must continue the Direction of the Meridian by Poles till he comes to an Eminence, or Place more convenient; there he is to mark a Point with a Pole, and setting up another perpendicular Pole at a Distance, in a Line with the Principal's Signal, let him order his Tent to be taken down, as a Signal for the Principal to take down his, and to come away with it and with all his other Things. Then, over the Direction of the Meridian found by the Assistant the Principal must pitch his Tent, hang two Plumb-lines within it on the Meridian, and proceed as before to continue it farther.

If a Town, Wood, Building, high Wall, or other Obftacle, fhall happen in the Way, fo as to hinder the Continuation of the meridian Line, as the Wood X in Plate III. Fig. 9. then, before you reach fuch Obftacle, on a fmooth Plane mark off with the Sextant A B a Perpendicular to the Meridian, and meafure in that Line as great a Length as will extend beyond the Obftacle, fo that the Perpendicular B C raifed on the End of the Meafurement may fall on one Side of the Obftacle; and continue B C, if neceffary, with upright Poles, till you find a fmooth Plane extending perpendicularly crofs the Direction of the Meridian; on that Plane make C D perpendicular to B C, and meafure from C to D a Diftance equal to A B, and D will be a Point in the Meridian continued from A. Then a Perpendicular D E, on the Line C D, will be a Continuation of the original Meridian: by upright Poles placed in thefe two Points, and other Poles in their Direction, it may be continued farther at Pleafure.

If A B, the Perpendicular, cannot be meafured exactly, becaufe of the Unevennefs of the Ground, mark a Line in another Direction, where the Ground is level, as A F, or A G, and take the Angle M A F, or M A G; at F, make the Angle A F C = M A F; and F C will be parallel to M A; or at G, if that is the Direction chofen, make the Angle A G C = M A G, and G C will be parallel to M A. Then in the right-angled Triangle A B F, or A B G, having the Hypothenufe A F, or A G; and, in the firft, the Angle A F B, equal to the Supplement of A F C, or, in the other, the Angle A G B = M A G, thence, by Protraction, or Calculation, find the Perpendicular A B, and note it down. At C mark C D a Perpendicular to C B; on it meafure the Length of A B, and it will terminate in D, a Point in the Meridian M A continued.

If a Perpendicular C D cannot be meafured exactly, then mark out a Line on either Side of it where the Ground is level, as C H, or C I; take the Angle B C H, or B C I, according to the Direction affumed, and from thence, having the Length of the Perpendicular C D = A B, and the Angle D C H = B C H — 90°, or the Angle D C I = 90 — B C I, the Hypothenufe C H, or C I, may be found: meafure that on the Ground, and it will terminate in H, or I, a Point in the Meridian M A continued. At H, on C H, make the Angle C H E = M A F; or, at the Point I, the Angle C I E = M A G, and E will be another Point in the Meridian M A continued,

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nued,

nued.   Place perpendicular Poles in thefe two Points, and by them continue the Meridian to fome Eminence where a diftant View foreward may be had; there pitch your Tent over the meridian Line, hang up the Plumb-lines in it, and examine your Meridian by the Stars before you proceed farther, in Cafe the meafuring fhould have occafioned any Inaccuracy; correct the Error, if there is any, and then proceed as before, by taking the magnetic Bearing of the Meridian, and of fome diftant Eminence on one Side of it, and fending your Affiftant to pitch his Tent on that Eminence, in order to make the neceffary Obfervations there, and find out the Direction of the Meridian; and continue the fame Procefs till you reach the End of the Territory propofed.

The Foundation of the foregoing Operations, in getting over Obftructions, is fo obvious from the Properties of parallel Lines, that it needs no Explanation to one who is acquainted with the firft Book of Euclid's Elements. It may however be proper to obferve, that, if the Meafurements are not made on fmooth Planes, with great Care, and the Angles taken and fet off on the Ground with great Exactnefs, it may make a fenfible Deviation in the Meridian : and that therefore, after fuch an Operation, it will generally be expedient to find the Meridian anew by the Stars, and proceed to continue the Direction of it as before.   But whether fuch Obftructions are met with or not, it will be prudent, every 80, or 100 Miles, to examine the Meridian by the Stars, that if any fmall Inaccuracy has arifen, it may not affect the fubfequent Parts of it.

SECTION   III.

How to trace a Parallel of Latitude through a Kingdom.

Provide a good portable Inftrument for taking the meridian Altitude of the Sun, or a Star, to Parts of a Minute.   A Sextant of three Feet Radius, with a convenient Stand to fupport it, may be fufficient.

At the Place whofe Parallel is to be traced, find the Latitude, and an exact meridian Line : fet off, by Poles placed upright in the Ground, a Perpendicular to the Meridian, and continue that Line about one Degree of
Longitude,

Longitude, (suppose 30 or 40 Miles) till you come to a level Plane extending about one Mile northward, or toward the elevated Pole; there find the Latitude and a meridian Line: on that meridian Line continued through the Plane, measure a Distance equal to the Difference of the first and last Latitude (which will be less than one Mile) and it will terminate in a Point of the Parallel required. Another Point in it may be marked about the Middle of the Perpendicular to the first Meridian: for the Tangent of half a Degree falls very little without the Arc.

At the first-mentioned Point in the Parallel, mark off with Poles a Perpendicular to the Meridian as before; continue it 30 or 40 Miles forward till you find another level Plare; there observe the Latitude and find a meridian Line: on that Meridian measure the Difference of the first and last Latitudes, and that Measurement will terminate in another Point of the Parallel: and the Middle of the Perpendicular to the former Meridian will be a fourth Point. Proceed in the same Manner to find other Points as far eastward, or westward as is necessary, and straight Lines on the Ground joining these several Points will mark out on the Ground the Parallel of Latitude of the Place required; or more strictly a Polygon not sensibly differing from it.

The Polygon will be still nearer a Circle, if a Perpendicular is continued East and West from each of the Meridians, and two Points of the Parallel are marked in each of these Perpendiculars, one on one Side of the crossing Meridian, the other on the other Side, and about one third of a degree of Longitude from it.

If it shall happen that a smooth Plane is not to be had for measuring the Difference of the two Latitudes along the Meridian, measure a straight Line in any other Direction making an Angle with the Meridian; find that Angle by the Sextant, and you will then have two Sides of a Triangle (the Difference of Latitude and the measured Line) and the Angle comprehended between them, to find another Angle, which second Angle observed and marked off by a Pole in the Ground will determine the Direction of the third Side; and where it intersects the Meridian will be a Point in the Parallel of Latitude sought.

The

The Exactness of this Operation depends chiefly on the Accuracy of the Instrument with which the several Latitudes are taken : the Sextant, therefore should be carefully adjusted immediately before each Observation.

T H E   E N D.

ERRATA.

Page 19. Line 22, *after* towards S, *read* as at k.——p. 23. l. 8, *after* A S B, *read* (Fig. 17 and 18.)——p. 27. l. 1, *for* Pales, *read* Poles.——p. 34. l. 16, *for* Horizon, *read* Horizons.——p. 36. l. 16, *after* true Angle, *read* To *prevent* it, the Index should be of a Substance not apt to bend, and as broad as the Sextant can conveniently admit of; it should move quite easy round the Center; but by means of a spring and screw should compress the Arch of the Instrument with requisite Firmness, and so as to slide smoothly along it when moved.——p. 55. l. *last but two, for* d Q, *read* D E.——p. 59. l. 22, *for* wuond, *read* wound.——p. 88. l. 16, *for* Objed, *read* Objects.

PLATE. I.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.

Fig. 9.

Fig. 10.

Fig. 11.

Fig. 12.

Fig. 13.

Fig. 14.

Fig. 15.

Fig. 16.

Fig. 17.

Fig. 18.

Fig. 19.

PLATE II.

Fig. 1.

n

m

l

k

C

Church Point

B

A

Rock Head

Rock

i
h
g
f
d
e

c Y

b

a X

D

Fig. 2.

PLATE II.

F. Bodge Sculp.

PLATE III.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.

Fig. 9.
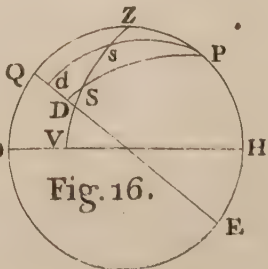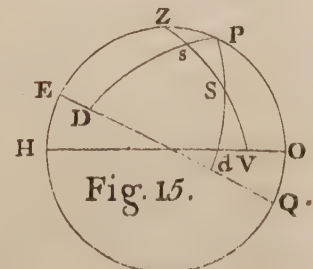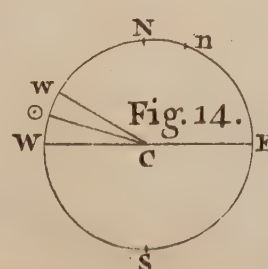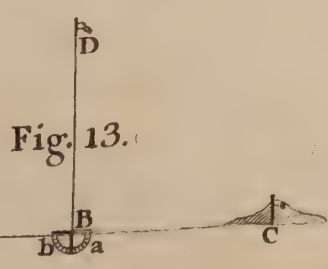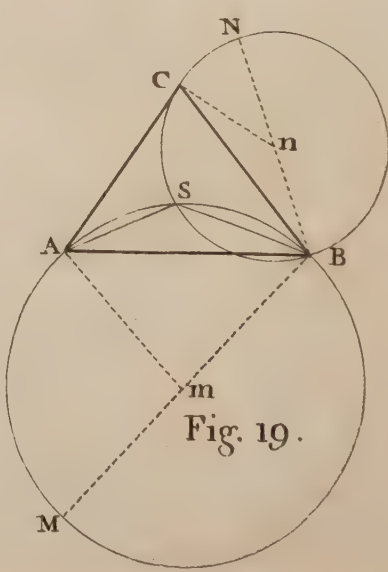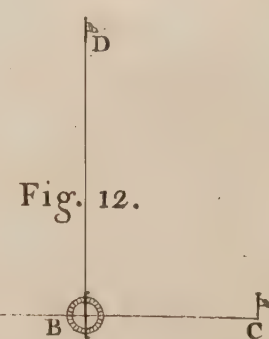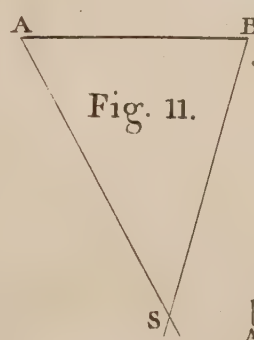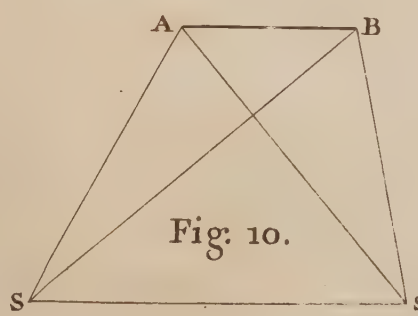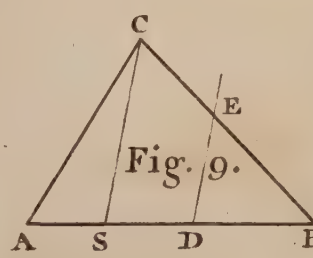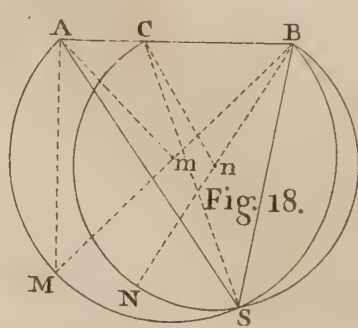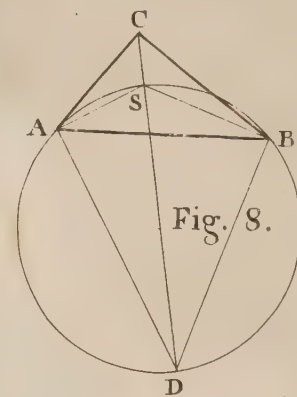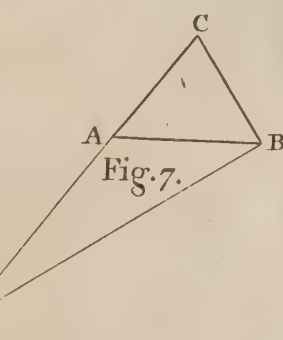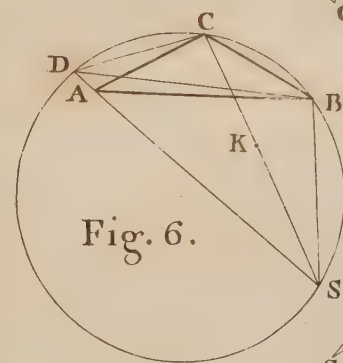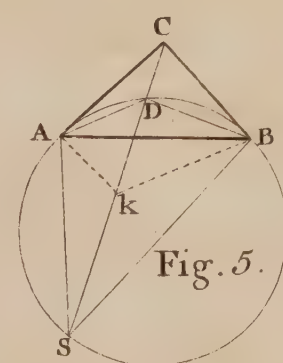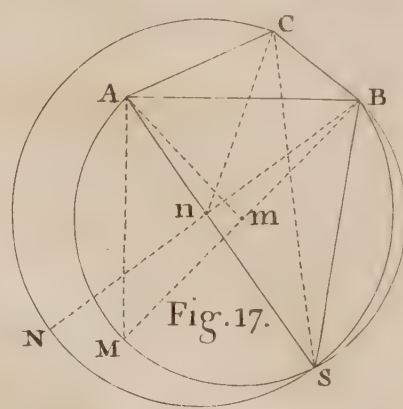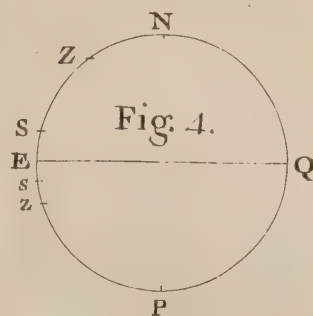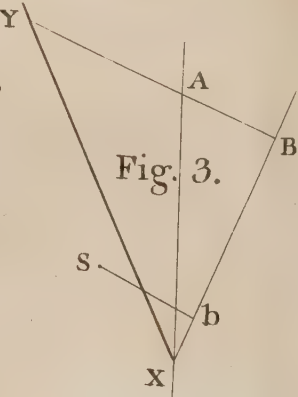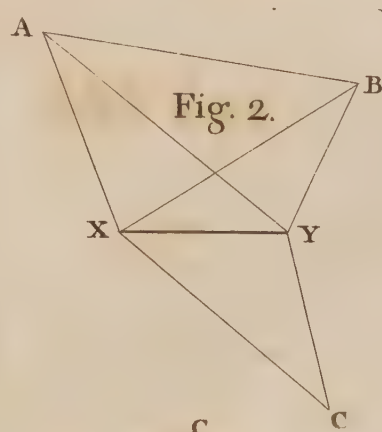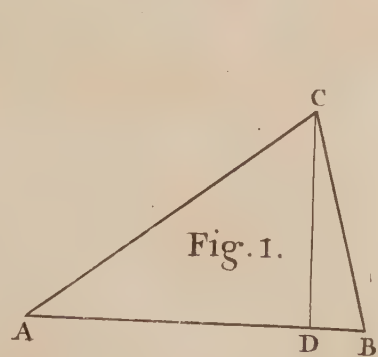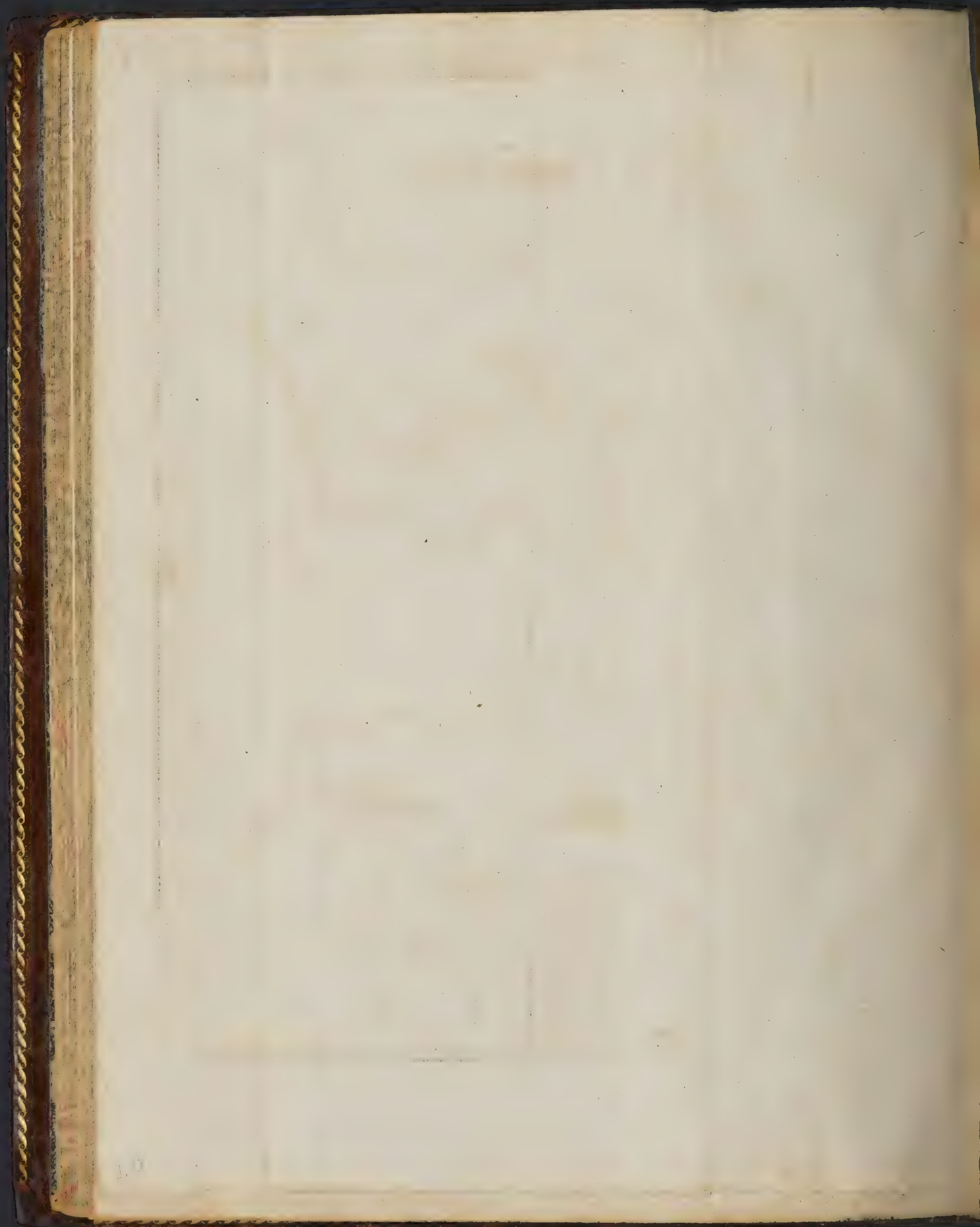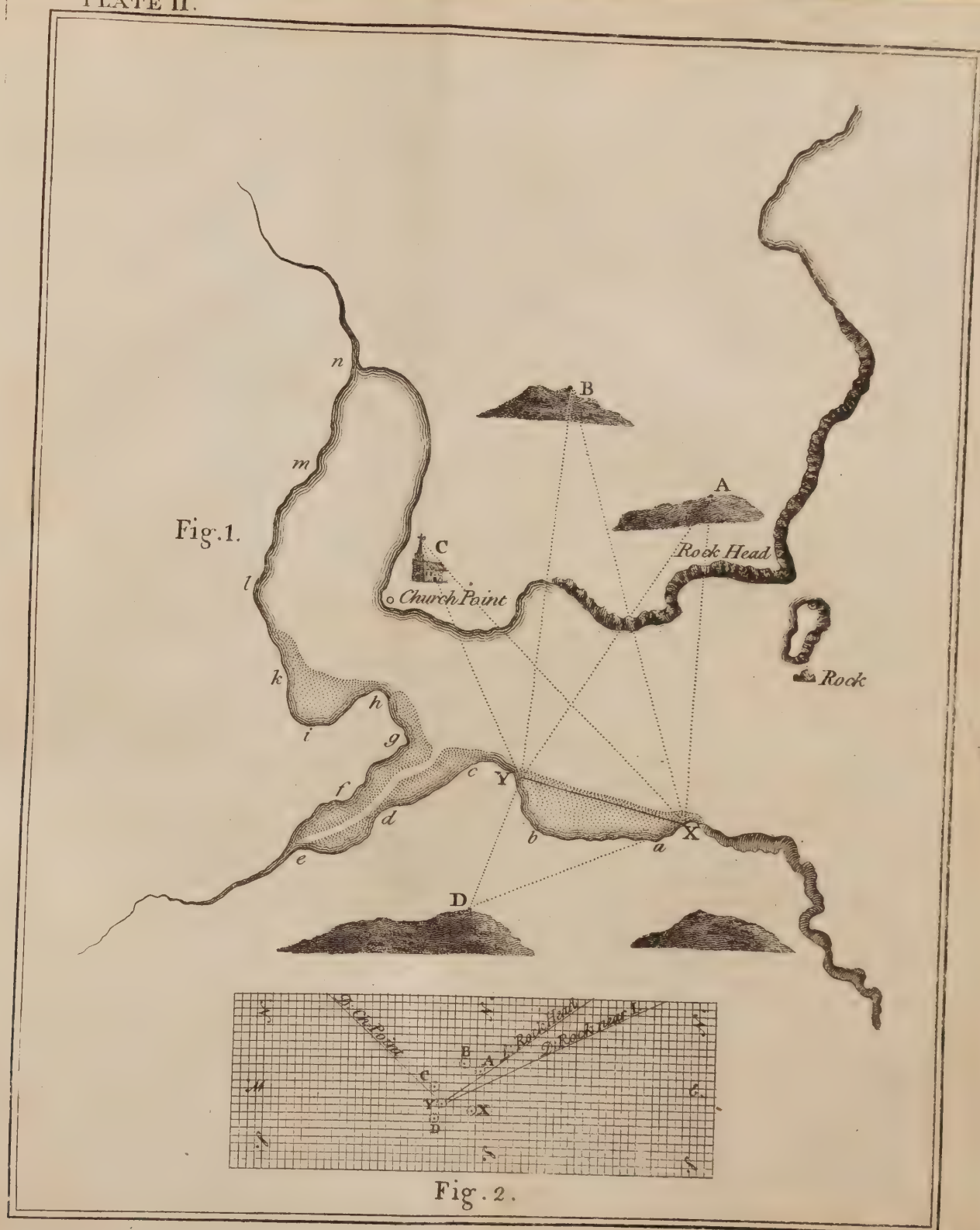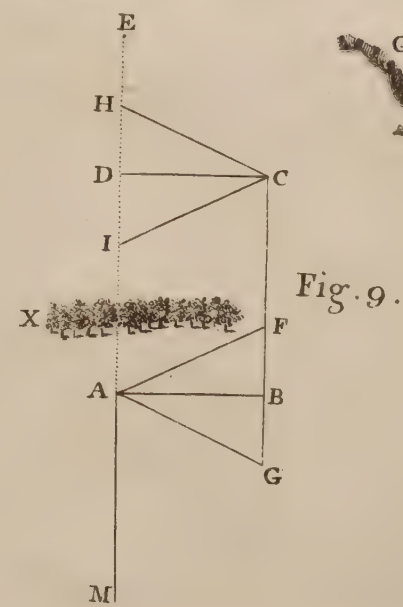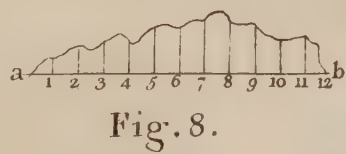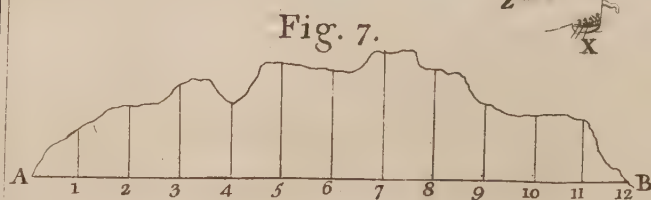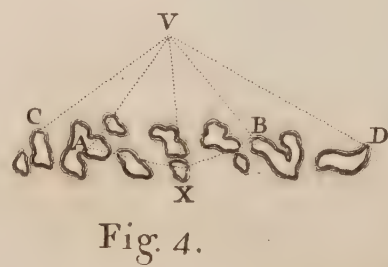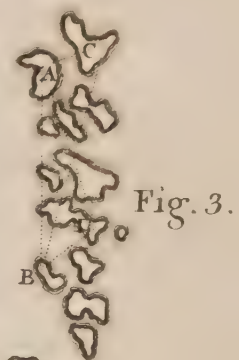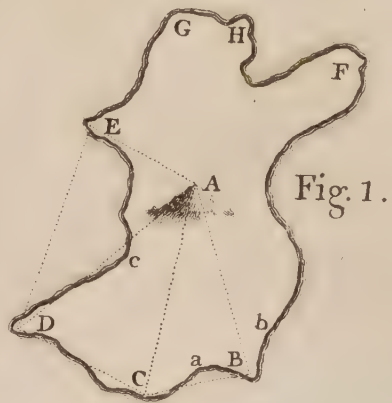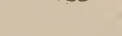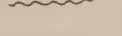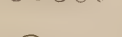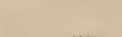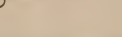
PLATE.IV.

Marks and Diversities to be represented in Draughts.

Rocky Cliffs.

Grassy, or Clay Cliffs.

Low Rocky Shores.

Low Sandy Shores.

Sandy Soil near the Shore.

Rocks always above Water.

Rocks that dry and are covered daily.

Rocks that dry with Spring-tide only.

Rocks always below Water.

Sand-banks that dry and are covered daily.

Sand-banks dry with Spring-tide only.

Sand-banks always below Water.

The safest Anchorage.

Stopping-Places.

The best Channel.

An Eddy.

Overfalls; or rough, breaking Seas.

Whirlpools.

Leading-marks, for avoiding Rocks and Shoals.

The Direction of the Stream of Flood.

Beacons, or Perches.

A Can and Cask Buoy.

Below the Soundings, (r) signifies rocky Ground; (c) Clay; (m) Mud, or Ouze; (g) Gravel; (s) Sand; (sh) Shells, or Shell Sand; (st) large Stones; (co) small Corral; (sg) Sand and Gravel; (ssh) Sand and Shells. The numeral Letters shew the Time of High-water on the full & change Days of the Moon. Perpendicular Rise of ordinary Spring-tide   Feet; of Neap-tide   Feet.

J. Lodge Sculp.